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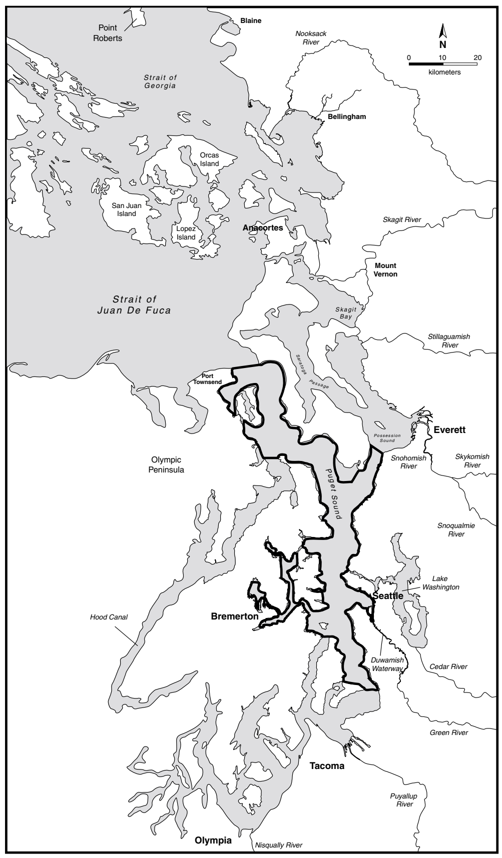
WASHINGTON STATE DEPARTMENT OF ECOLOGY

Sediment Quality in Puget Sound

Year 2 - Central Puget Sound

December 2000



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Sediment Quality in Puget Sound

Year 2 - Central Puget Sound

December 2000

by

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Waterbody Numbers

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WA-15-0030	WA-PS-0230
WA-15-0040	WA-PS-0240
WA-15-0050	WA-PS-0270
WA-17-0020	

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Acronyms and Abbreviations

AVS/SEM –	acid volatile sulfides/ simultaneously-extracted metals
AED –	atomic emission detector
B[a]P –	benzo[a]pyrene
BNA –	base/neutral/acid organic compound analysis
CAS –	Columbia Analytical Services
CLIS –	Central Long Island Sound
COH –	chlorinated organic hydrocarbons
CSL –	cleanup screening level (Washington State Sediment Management Standards – chapter 173-204 WAC)
CV –	coefficient of variation
DCM –	dichloromethane
DMSO –	dimethylsulfoxide
EAP –	Environmental Assessment Program
EC50 –	50% effective concentration; concentrations of the extract that inhibited luminescence by 50% after a 5-minute exposure period (Microtox™ analysis)
ERL –	effects range low (Long et al., 1995)
ERM –	effects range median (Long et al., 1995)
LC50 –	lethal concentration for 50% of test animals
LOEC –	lowest observable effects concentration
LPL –	lower prediction limit
MEL –	Manchester Environmental Laboratory
MSD	minimum significant difference
MSMT –	Marine Sediment Monitoring Team
NaCl	sodium chloride
NOAA –	National Oceanic and Atmospheric Administration
NOEC –	no observable effects concentration
NS&T –	National Status and Trends Program
PAH –	polynuclear aromatic hydrocarbon
PCB –	polychlorinated biphenyl
PSAMP –	Puget Sound Ambient Monitoring Program
QL –	quantitation limit reported by Manchester Environmental Laboratory for chemistry data
RGS –	reporter gene system
RLU –	relative light unit
SDI –	Swartz's Dominance Index
SDS –	sodium dodecyl sulfate
SMS –	Sediment Management Standards
SQS –	sediment quality standard (Washington State Sediment Management Standards – chapter 173-204 WAC)
TAN –	total ammonia nitrogen
TCDD –	tetrachlorodibenzo-p-dioxin
TEQ –	total equivalency quotients
TOC –	total organic carbon
UAN –	un-ionized ammonia
UPL –	upper prediction limit

Abstract

As a component of a three-year cooperative effort of the Washington State Department of Ecology and the National Oceanic and Atmospheric Administration, surficial sediments from 100 locations in central Puget Sound were tested in 1998 to determine their relative quality. The purpose of this survey was to determine the quality of sediments in terms of the severity, spatial patterns, and spatial extent of chemical contamination, toxicity, and adverse alterations to benthic infauna. The survey encompassed an area of approximately 732 km^2, ranging from Port Townsend south to Des Moines in the central region of Puget Sound. Data from the chemical analyses indicated that toxicologically significant contamination was restricted in scope to a relatively minor portion of the region. However, sediments from several sampling locations within Elliott Bay and other locations had relatively high chemical concentrations. Data from toxicity tests indicated that many of the samples from inner Elliott Bay, including the lower Duwamish River, and Sinclair Inlet were relatively toxic. Toxicity also was observed in additional samples from locations scattered throughout the region. Wide ranges in several numerical indices of benthic infaunal structure were observed, but the majority of samples had diverse and abundant populations of benthos representative of conditions typical of the area. Eighteen samples in which chemical concentrations were relatively high, toxicity was apparent, and benthic communities appeared to be affected represented 1.1% of the study area. Samples in which chemical contamination and toxicity were observed, but the benthos was relatively abundant and diverse, represented 12.5% of the study area. Samples that were not contaminated, not toxic, and had abundant benthic communities represented 49.1% of the survey area, while samples which displayed either toxicity or chemical contamination (but not both) and abundant benthic communities represented 37.3% of the survey area. Generally, upon comparison, the number of stations displaying degraded sediments based upon the sediment quality triad of data was slightly greater in the central Puget Sound than in the northern Puget Sound study, although the percent of the total study area degraded in each region was similar (1.3 and 1.1%, respectively). In comparison, the Puget Sound sediments were considerably less degraded than those from other NOAA sediment surveys conducted nationwide.

Executive Summary

Numerous studies of Puget Sound have documented the degree of chemical contamination and associated adverse biological effects within many different urbanized bays and harbors. Data from previous research has shown that contamination occurred in sediments, water, sea surface microlayers, fishes, benthic invertebrates, sea birds, and marine mammals in parts of Puget Sound. Additionally, the occurrence of severe toxicity of sediments in laboratory tests, significant alterations to resident benthic populations, severe histopathological conditions in the organs of demersal fishes, reduced reproductive success of demersal fishes and marine mammals, acute toxicity of sea surface microlayers, uptake and bioaccumulation of toxicants in sea birds and marine mammals suggested that chemical contamination was toxicologically significant in Puget Sound. However, none of the previous surveys attempted to quantify the areal or spatial extent of contamination or toxicant-related effects. Therefore, although numerous reports from previous studies indicated the severity or degree of contamination and adverse effects, none reported the spatial scales of the problems.

The overall goal of the cooperative program initiated by the Washington State Department of Ecology (Ecology) as a part of its Puget Sound Ambient Monitoring Program (PSAMP) and the National Oceanic and Atmospheric Administration (NOAA) as a part of its National Status and Trends Program (NS&TP) was to quantify the percentage of Puget Sound in which sediment quality was significantly degraded. The approach selected to accomplish this goal was to measure the components of the sediment quality triad at sampling locations chosen with a stratified-random design. One hundred sediment samples were collected during June/July, 1998, at locations selected randomly within 32 geographic strata that covered the area from Port Gardner Bay near Everett and Port Townsend south to Des Moines. Strata were selected to represent conditions near major urban centers (e.g., Seattle, Bremerton) and marine areas adjacent to less developed areas. The 32 strata encompassed an area of approximately 732 km^2.

Chemical analyses were performed on all samples to quantify the concentrations of trace metals, petroleum constituents, chlorinated pesticides, other organic compounds, and the physical/sedimentological characteristics of the sediments. Chemical concentrations were compared to applicable numerical guidelines from NOAA and state criteria for Washington to determine which samples were contaminated. A battery of four toxicity tests was performed on all samples to provide information from a variety of toxicological endpoints. Results were obtained with an acute test of survival among marine amphipods exposed to solid phase sediments. The toxicity of sediment pore waters was determined with a test of fertilization success among sea urchin gametes. A microbial bioluminescence test of metabolic activity was performed in exposures to organic solvent extracts along with a cytochrome P450 HRGS activity test in exposures to portions of the same solvent extracts. Resident benthic infauna were collected to determine the relative abundance, species richness, species composition, and other characteristics of animals living in the sediments at each site.

The area in which highly significant toxicity occurred totaled approximately 0.1% of the total area in the amphipod survival tests; 0.7%, 0.2%, and 0.6% of the area in urchin fertilization tests of 100%, 50%, and 25% pore waters, respectively; 0% of the area in microbial bioluminescence tests; and 3% of the area in the cytochrome P450 HRGS assays. The estimates of the spatial extent of toxicity measured in three of the four tests in central Puget Sound were considerably lower than the "national average" estimates compiled from many other surveys previously conducted by NOAA. Generally, they were comparable to the estimates for northern Puget Sound. However, in the cytochrome P450 HRGS assays, a relatively high proportion of samples caused moderate responses. Collectively, these data suggest that central Puget Sound sediments were not unusually toxic relative to sediments from other areas. The large majority of the area surveyed was classified as non-toxic in these tests. However, the data from the RGS assays indicated a slight to moderate response among many samples.

The laboratory tests indicated overlapping, but different patterns in toxicity. Several spatial patterns identified with results of all the tests were apparent in this survey. First, highly toxic responses in the sea urchin, Microtox, and P-450 tests were observed in many samples from inner reaches of Elliott Bay. Toxicity in these tests decreased considerably westward into the outer and deeper regions of the bay. Second, many of the samples from the Liberty Bay and Bainbridge basin area were toxic in the Microtox and P-450 assays. The degree of toxicity decreased steadily southward down the Bainbridge basin to Rich Passage, where the sediments were among the least toxic. Third, samples from two stations located in a small inlet off Port Washington Narrows were among the most toxic in two or more tests. Fourth, several samples from stations scattered within Sinclair Inlet indicated moderately toxic conditions; toxicity diminished steadily eastward into Rich Passage. Finally, samples from the Admiralty Inlet/Port Townsend area and much of the central main basin were among the least toxic.

The surficial area in which chemical concentrations exceeded effects-based sediment guidelines was highly dependent upon the set of critical values that were used. There were 25 samples in which one or more Effects Range-Median (ERM) values were exceeded. They represented an area of about 21 km^2, or about 3% of the total survey area. In contrast, there were 94 samples in which at least one Washington State Sediment Quality Standard (SQS) or Cleanup Screening Level (CSL) value was exceeded, representing about 99% of the survey area. Without the data for benzoic acid, only 44 samples had at least one chemical concentration greater than a SQS (representing 25.2% of the area) and 36 samples had at least one concentration greater than a CSL (21% of the area).

The highest chemical concentrations invariably were observed in samples collected in the urbanized bays, namely parts of Elliott Bay and Sinclair Inlet. Often, these samples contained chemicals at concentrations that equaled or exceeded numerical guidelines or state standards. Concentrations generally decreased steadily away from these two bays and were lowest in Admiralty Inlet, Possession Sound, Rich Passage, Bainbridge Basin, and most of the central basin.

Although the study was not intended to determine the causes of toxicity in the tests, a number of statistical analyses were conducted to estimate which chemicals, if any, may have contributed to toxicity. As expected, strong statistical associations between measures of toxicity and complex mixtures of PAHs, pesticides, phenols, other organic compounds, and several trace metals were observed. However, there was significant variability in some of the apparent correlations, including samples in which chemical concentrations were elevated and no toxicity was observed.

Therefore, it is most likely that the chemical mixtures causing toxicity differed among the different toxicity tests and among the regions of the survey area.

Several indices of the relative abundance and diversity of the benthic infauna indicated very wide ranges in results among sampling stations. Much of this variability could be attributed to large differences in depth, sediment texture, organic carbon content, proximity to rivers, and other natural habitat-related factors.

Statistical analyses of the toxicity data and benthic data revealed few consistent relationships. Some indices of benthic community diversity and abundance decreased with increasing toxicity and others increased. Also, the relationships between measures of benthic structure and chemical concentrations showed mixed results.

Data from the chemical analyses, toxicity tests, and benthic community analyses, together, indicated that, of the 100 stations sampled, 36 had sediments with significant toxicity and elevated chemical contamination. Of these, 18 appeared to have benthic communities that were possibly affected by chemical contaminants in the sediments. They included stations in Sinclair Inlet, Dyes Inlet, Elliott Bay and the Duwamish River. These stations typically had moderate to very high total abundance, including high numbers of *Aphelochaeta* species N1 and other pollution-tolerant species, moderate to high taxa richness, low evenness, and low Swartz's Dominance Index values, and often, pollution-sensitive species such as arthropods and echinoderms were low in abundance or absent from these stations. These 18 stations represented an area of 8.1 km^2, or about 1.1% of the total survey area, while the remaining other 18 stations represented 12.5% of the area. Twenty-five stations located in Port Townsend, Admiralty Inlet, Possession Sound, the central basin, Port Madison, Liberty Bay, the Bainbridge Basin, Rich Passage, Dyes Inlet, and outer Elliott Bay, were identified with no indications of significant sediment toxicity or chemical contamination, and with abundant and diverse populations of benthic infauna. These stations represented an area of 359.3 km^2, equivalent to 49% of the total survey area. The remaining thirty-nine stations, located in Port Townsend, Possession Sound, the central basin, Eagle Harbor, Liberty Bay, the Bainbridge Basin, and Elliott Bay and the Duwamish River, displayed either signs of significant chemical contamination but no toxicity, or significant toxicity, but no chemical contamination, and for the majority, the benthic populations were abundant and diverse. Together, these stations represented an area of 272.6 km^2, equivalent to 37% of the total central Puget Sound study area.

The distribution of the "triad" results was somewhat different from that determined for 100 northern Puget Sound samples (Long et al., 1999a). There were 18 samples from central Puget Sound (1.1% of the study area) and 10 samples from northern Puget Sound (1.3% of the study area) in which all three components of the triad indicated degraded conditions. Sixteen and 18 (10.6 and 12.5% of the study areas) samples from north and central Puget Sound, respectively, displayed both toxicity and chemical contamination, but diverse benthos. Twenty-five (49.1%) of the central Puget Sound and 21 (19.6%) of the samples from northern Puget Sound indicated non-degraded conditions. Finally, there were 53 samples collected from northern Puget Sound (68.5% of the study area) that displayed either significant chemistry or toxicity results (but not both), and whose infaunal assemblages were varied, while only 39 stations (37.3% of the study area) showed these characteristics in central Puget Sound.

Data from this central Puget Sound study will, in the future, be merged with those from northern (sampled in 1997) and southern (sampled in 1999) Puget Sound to provide an area-wide assessment of the quality of sediments in the entire Puget Sound Basin. These data also provide the basis for comparison of Puget Sound sediment data with sediment data collected nationwide during other NOAA surveys.

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Introduction

Project Background

In 1996 the Washington Department of Ecology (Ecology) and the National Oceanic and Atmospheric Administration (NOAA) entered into a three-year Cooperative Agreement to quantify the magnitude and extent of toxicity and chemical contamination of sediments in Puget Sound. This agreement combined the sediment monitoring and assessment programs of the two agencies into one large survey of Puget Sound.

Ecology's Marine Sediment Monitoring Team has conducted the Sediment Monitoring Component of the Puget Sound Ambient Monitoring Program (PSAMP) since 1989. This program used the sediment quality triad approach of Long and Chapman (1985) to determine relative sediment quality in Puget Sound. Preceding the joint surveys with NOAA, Ecology established baseline data for toxicity and chemical contamination of Puget Sound sediments (Llansó et al., 1998a) and characterized infaunal invertebrate assemblages (Llansó et al., 1998b) at 76 selected monitoring stations throughout Puget Sound. A portion of this baseline work is continuing as a subset of ten stations at the present time.

The National Status and Trends (NS&T) Program of NOAA has conducted bioeffects assessment studies in more than 30 embayments and estuaries nationwide since 1990 (Long et al., 1996). These studies followed a random-stratified sampling design and the triad approach to estimate the spatial extent, magnitude, and spatial patterns in relative sediment quality and to determine the relationships among measures of toxicity, chemical contamination, and benthic infaunal structure within the study areas. NOAA chose to continue these studies in Puget Sound because of the presence of toxicants in sufficiently high concentrations to cause adverse biological effects, the lack of quantitative data on the spatial extent of toxicity in the area, and the presence and experience of a state agency partner (Ecology) in performing the study.

The current joint project of Ecology and NOAA utilizes NOAA's random-stratified sampling design and the sediment quality triad approach for the collection and analyses of sediment and infauna in northern Puget Sound sampled in 1997 (Long et al., 1999a), central Puget Sound sampled in 1998 (described in this report), and southern Puget Sound sampled in 1999.

Site Description

The three-year study area encompassed the basins and channels from the U.S./Canada border to the southern-most bays and inlets near Olympia and Shelton and included the waters of Admiralty Inlet and Hood Canal (Figure 1). This region, located in northwestern Washington, is composed of a variety of interconnected shallow estuaries and bays, deep fjords, broad channels and river mouths. It is bounded by three major mountain ranges; the Olympics to the west, the mountains of Vancouver Island to the north, and the Cascade Range to the east. The northern end of Puget Sound is open to the Strait of Juan de Fuca and the Strait of Georgia, connecting it to the Pacific Ocean. The estuary extends for about 130 km from Admiralty Inlet at the northern end of the main basin to Olympia at the southern end, and ranges in width from 10 to 40 km (Kennish, 1998).

The main basin of Puget Sound was glacially scoured with depths up to 300 m, has an area of 2600 km^2 and a volume of 169 km^3 (Kennish, 1998). Circulation in Puget Sound is driven by complex forces of freshwater inputs, tides, and winds. Puget Sound is characterized as a two-layered estuarine system, with marine waters entering the Sound at the sill in Admiralty Inlet from the Strait of Juan de Fuca at depths of 100 to 200 m, and freshwater entering from a number of large streams and rivers. Major rivers entering Puget Sound include the Skagit, Snohomish, Cedar, Duwamish, Puyallup, Stillaguamish, and Nisqually (Figure 1). The Skagit, Stillaguamish, and Snohomish rivers account for more than 75% of the freshwater input into the Sound (Kennish, 1998). The mean residence time for water in the central basin is approximately 120-140 days, but is much longer in the isolated inlets and restricted deep basins in southern Puget Sound.

The bottom sediments of Puget Sound are composed primarily of compact, glacially-formed, clay layers and relict glacial tills (Crandell et al., 1965). Major sources of recent sediments are derived from shoreline erosion and riverine discharges.

Puget Sound is a highly complex, biologically important ecosystem that supports major populations of benthic invertebrates, estuarine plants, resident and migratory fish, marine birds, and marine mammals. All of these resources depend upon uncontaminated habitats to sustain their population levels. The Sound is bordered by both relatively undeveloped lands and highly urbanized and industrialized areas. Major urban centers include the cities of Seattle, Tacoma, Olympia, Everett, Bremerton, and Bellingham.

The portion of the Puget Sound study conducted in 1998 focused upon the central region of the study area, from Admiralty Inlet and the southern boundary of the 1997 study area (i.e., Mukilteo) to Maury Island (Figure 1). The 1998 study area, therefore, included portions of Port Townsend Bay, Admiralty Inlet, southern Possession Sound, the main (or central) basin of Puget Sound, Port Madison, Eagle Harbor, Liberty Bay, Dyes Inlet, Port Washington Narrows, Sinclair Inlet, Rich Passage, Elliott Bay, the lower Duwamish River, East Passage, and the area surrounding Blake Island.

Toxicant-Related Research in Central Puget Sound

Puget Sound waters support an extremely diverse spectrum of economically important biological resources. In addition to extensive stocks of salmon, a variety of other species (e.g. cod, rockfish, clams, oysters, and crabs) support major commercial and recreational fisheries. Studies have shown that high concentrations of toxic chemicals in sediments are adversely affecting the biota of Puget Sound via detritus-based food webs. Studies of histopathological, toxicological, and ecological impacts of contaminants have focused primarily on biota collected in areas potentially influenced by port activities and municipal or industrial discharges (Ginn and Barrick, 1988). Therefore, the majority of effects studies have focused on both Elliott and Commencement Bay in central Puget Sound.

Considerable research has been conducted on the presence, concentrations, and biological significance of toxicants in the central region of Puget Sound. Much of this research was conducted to quantify chemical concentrations in sediments, animal tissues, water, marine mammals, marine birds, and sea surface microlayers. Some studies also were conducted to determine the history of chemical contamination using analyses of age-dated sediment cores. The objectives of these studies often included analyses of the biological significance of the chemical mixtures. Biological studies have been conducted to determine the frequency of lesions and other disorders in demersal fishes; the toxicity of sediments; the toxicity of water and sea surface microlayers; reproductive dysfunction in fishes, birds, and mammals; and the degree of effects upon resident benthic populations.

Much of the previous research on toxicant effects in central Puget Sound focused upon areas of Elliott Bay, the lower Duwamish River, Sinclair Inlet, and Eagle Harbor as well as the central basin in the vicinity of the West Point wastewater discharge. Port Madison often was used as a reference area for studies of toxicant effects elsewhere. NOAA, the U. S. Environmental Protection Agency, and Seattle METRO funded much of the work.

Studies performed by NOAA through the MESA (Marine Ecosystems Analysis) Puget Sound Project determined the concentrations of toxic substances and toxicity in sediments with a battery of acute and chronic tests performed on samples collected throughout most of the Puget Sound region. The sediment toxicity surveys were conducted in a sequence of four phases in the early 1980's. In the first phase (Chapman et al., 1982), samples collected from 97 locations were tested with several bioassays. Samples were collected mainly at selected locations within Elliott Bay, Commencement Bay, and Sinclair Inlet. Tests were performed to determine survival of oligochaetes, amphipods, and fish; respiration measurements of oligochaetes; and chromosomal damage in cultured fish cells. The results of multiple tests indicated that some portions of Elliott Bay near the Denny Way CSO and several of the industrialized waterways of Commencement Bay were highly toxic and samples from Port Madison were among the least toxic.

In the second phase of the Puget Sound sediment toxicity surveys, tests were performed to identify diminished reproductive success among test animals exposed to sediments (Chapman et al., 1983). These tests involved oyster embryo development, surf smelt development, and a polychaete worm life cycle bioassay. Samples from the lower Duwamish River and the Commencement Bay waterways were the most toxic. In the third phase, 22 samples were collected in Everett Harbor, Bellingham Bay, and Samish Bay in northern Puget Sound and tested with the same battery of tests used in the first phase of the studies (Chapman et al., 1984a). Toxicity was less severe in these 22 samples than in comparable samples from Elliott and Commencement bays. However, the sediments from Everett Harbor demonstrated greater toxicity than those from Bellingham Bay and samples from Samish Bay were the least toxic.

In the fourth and final phase, sediment quality was determined with the introduction of the sediment quality triad approach (Chapman et al., 1984b; Long and Chapman, 1985). Matching chemical, toxicity, and benthic data were compiled to provide a weight of evidence to rank sampling sites. Data from several locations in Elliott and Commencement bays and Sinclair Inlet were compared with data from Case Inlet and Samish Bay. As observed in the previous phases, the data clearly showed a pattern of low sediment quality in samples from the urbanized areas relative to those from the more rural areas.

Histopathology studies that included central Puget Sound indicated that biological impacts such as hepatic neoplasms, intracellular storage disorders, and lesions in fish were pollution-related. These disorders were found most frequently near industrial urban areas, including portions of Elliott Bay, Sinclair Inlet, and Eagle Harbor (Malins et al., 1980, 1982, 1983, 1984; U.S. EPA, Region X, 1986). Fish with such disorders often had the highest concentrations of organic compounds and trace metals in their tissues.

Studies in which toxicity tests were performed confirmed histopathological findings that pollution-induced biotic impacts are more likely to occur near industrial urban areas (Chapman et al., 1982; Malins, et al., 1982; Malins, 1985; Clark, 1986; Malins et al. 1985; Llansó et al., 1998a). Numerous analyses of contaminant exposures and adverse effects in resident demersal fishes were conducted in most of the urbanized bays and harbors (Malins et al. 1980, 1982a, 1984). Data from these studies demonstrated that toxicant-induced, adverse effects were apparent in fish collected in urban harbors of Puget Sound and the prevalence of these effects was highest in areas with highest chemical concentrations in the sediments to which these fish were exposed. The incidence of neoplastic lesions was highest among fish from Eagle Harbor. Similar kinds of analyses were performed on resident marine birds and marine mammals, demonstrating that chemical levels in these animals were elevated in regions of Elliott and Commencement bays relative to animals from the Strait of Juan de Fuca and elsewhere (Calambokidis et al., 1984).

A summary of available data from sediment toxicity tests performed in Puget Sound through 1984 (Long, 1984) indicated that sediments from the waterways of Commencement Bay, Elliott Bay off the Denny Way CSO, inner Sinclair Inlet, lower Duwamish Waterway, Quilcene Bay, Bellingham Bay, and inner Everett Harbor were among the most toxic in the entire area. Significant results were reported in acute survival tests with amphipods, sublethal assays of respiration rate changes, tests of mutagenic effects in fish cells, and oyster embryo development tests.

Studies of invertebrate communities conducted in central Puget Sound have indicated significant losses of benthic resources in some areas with high chemical concentrations (Malins, et al., 1982; Kisker, 1986; Chapman et al., 1984a,b; Broad et al., 1984; Llansó et al., 1998b). The longest term and most extensive sampling of infaunal invertebrate communities was conducted by the Puget Sound Ambient Monitoring Program, established in 1989. The program sampled 28 sites in northern Puget Sound, 13 of which were sampled yearly from 1989-95 and 15 that were sampled once in 1992 and once again in 1995.

The colonization rates and species diversity of epifaunal communities that attached to vertical test surfaces were lowest at locations in the lower Duwamish River as compared to sites elsewhere in Puget Sound (Schoener, 1983). Samples of sea surface microlayers from Elliott Bay were determined to be contaminated and toxic in acute tests done with planktonic life stages of marine fish (Hardy and Word, 1986; Hardy et al., 1987a,b). Historical trends in chemical contamination were reviewed and the physical processes that influence the fate and transport of toxicants in regions of Puget Sound were summarized in a variety of reports (Brown et al., 1981; Dexter et al., 1981; Barrick, 1982; Konasewich et al., 1982; Long 1982; Crecelius et al., 1985; Quinlan et. al, 1985).

Following the work by NOAA, additional studies of chemical contamination were supported by the Puget Sound National Estuary Program (PSEP). The PSEP studies further identified spatial patterns in sediment contamination, toxicity, and benthic effects in selected urban embayments and reference areas throughout Puget Sound (PTI, 1988; Tetra Tech, 1988). The PSEP also formulated tentative plans for cleaning up some of the more contaminated sites. Although extensive deep portions of Puget Sound and most rural bays were relatively contaminant-free, parts of the bays bordering urban, industrialized centers contained high concentrations of toxic chemicals (Long and Chapman, 1985; Llansó et al., 1998a). Other programs and studies, including the Puget Sound Dredged Disposal Analysis Program (PTI, 1989) and the Puget Sound Ambient Monitoring Program (Llansó et al., 1998a,b), characterized baseline sediment quality conditions and trends throughout Puget Sound.

In addition to these large-scale studies, federal, state and local government, as well as private industry, have conducted a vast number of smaller, localized studies on Puget Sound sediments, primarily for regulatory purposes. These studies have focused on the level of chemical concentrations in sediments, the incidence of abnormalities and diseases in fish and benthic invertebrates, the level and degree of sediment toxicity to various bioassay organisms, the relationship between sediment contamination and the composition of benthic invertebrate communities, and to a lesser extent, the associations between sediment contamination, toxicity, and resident marine bird and mammal populations.

Information gathered from the surveys of toxicity in sediment, water, and microlayer, and the studies of adverse effects in resident benthos, fish, birds and mammals confirmed that conditions were most degraded in urbanized embayments of Puget Sound, including Elliott Bay (Long, 1987). All of the data from the historical research, collectively, served to identify those regions of Puget Sound in which the problems of chemical contamination were the worst and in which management actions of some kind were most needed (NOAA, 1987). However, although these previous studies provided information on the degree and spatial patterns in chemical contamination and effects, none attempted to quantify the spatial extent of either contamination or measures of adverse effects.

The Sediment Quality Information System (SEDQUAL) Database

Ecology's Sediment Management Unit has compiled a database that includes sediment data from over 400 Puget Sound sediment surveys of various size and scope. The Sediment Quality Information System (SEDQUAL) database includes approximately 658,000 chemical, 138,000 benthic infaunal, and 36,000 bioassay analysis records from over 12,000 sample collection stations throughout Puget Sound. For the central Puget Sound study area defined in this report, the SEDQUAL database currently contains sediment data from 2063 samples (148 surveys) collected from 1950-1999. Using the analytical tools available in SEDQUAL, these data can be compared to chemical contaminant guidelines, the Sediment Quality Standards (SQS) and Puget Sound Marine Sediment Cleanup Screening Levels (CSL), set forth in the Washington State

Sediment Management Standards (SMS), Chapter 173-204 WAC. Of the 2063 SEDQUAL samples from central Puget Sound, 1034 have chemical contaminant levels that exceeded at least one SQS or CSL value. The majority of these stations are located near population centers, urban and industrial areas, and ports, including Elliott Bay and the Duwamish River, Sinclair Inlet, Dyes Inlet, Liberty Bay, and Eagle Harbor (Figure 2). A summary of the chemicals found in these central Puget Sound SEDQUAL samples which exceeded SMS values, including their sample location and total number of samples, is given in Appendix A. In central Puget Sound, all 47 chemicals with SMS values were exceeded on at least one occasion.

Goals and Objectives

The shared goal of this study for both the PSAMP Sediment Monitoring Component and NOAA's nationwide bioeffects assessment program was to characterize the ecotoxicological condition of sediments, as well as benthic infaunal assemblage structure, as a measure of adverse biological effects of toxic chemicals in central Puget Sound. Based upon chemical analyses of sediments reported in previous studies, it appeared that there were relatively high probabilities that concentrations were sufficiently high in some regions of the study area to cause acute toxicity and infaunal assemblage alterations. Data from toxicity tests were intended to provide a means of determining whether toxic conditions, associated with high concentrations of chemical pollutants, actually occurred throughout any of the area. Examination of infaunal assemblages was intended to determine whether sediment chemistry and toxicity conditions are correlated with patterns in infaunal community structure. Underlying these goals was the intent to use a stratified-random sampling design that would allow the quantification of the spatial extent of degraded sediment quality.

Based on the nature of sediment contamination issues in Puget Sound, and the respective mandates of NOAA and the state of Washington to address sediment contamination and associated effects in coastal waters, the objectives of the cooperative assessment of bioeffects in Puget Sound were to:

1. Determine the incidence and severity of sediment toxicity;

2. Identify spatial patterns and gradients in sediment toxicity and chemical concentrations;

3. Estimate the spatial extent of toxicity and chemical contamination in surficial sediments as percentages of the total survey area;

4. Describe the composition, abundance and diversity of benthic infaunal assemblages at each sampling location;

5. Estimate the apparent relationships between measures of sediment toxicity, toxicant concentrations, and benthic infaunal assemblage indices; and

6. Compare the quality of sediment from northern, central, and southern Puget Sound measured in the three phases of this study.

This report includes a summary of the data collected in 1998 and correlation analyses to examine toxicity, chemistry, and infaunal relationships. Results of further analyses relating toxicity, chemistry, and infaunal structure throughout the entire survey area will be reported in a subsequent document.

Methods

Standardized methods described in the Puget Sound Estuary Program protocols (PSEP, 1996a), previously used in the 1997 survey of northern Puget Sound (Long et al., 1999a), and previously followed in surveys of sediment quality conducted elsewhere in the U.S. by NOAA (Long et al., 1996) were followed in this survey. Any deviations from these protocols are described below.

Sampling Design

By mutual agreement between Ecology and NOAA, the study area was established as the area extending from Point Wilson near Port Townsend to Maury Island (Figures 1 and 3a). Regions and basins that were included in the survey area included the central basin of Puget Sound; Admiralty Inlet; Port Madison; Liberty Bay, Dyes Inlet, Sinclair Inlet, and inter-connecting waterways west of Bainbridge Island; Eagle Harbor; and Elliott Bay and the adjoining lower Duwamish River. All samples were collected in depths of 6 ft or more (mean lower low water), the operating limit of the sampling vessel.

A stratified-random sampling design similar to those used in previous surveys conducted nationwide by NOAA (Long et al., 1996) and in the first year of this study in northern Puget Sound (Long et al., 1999a), was applied in central Puget Sound. This approach combines the strengths of a stratified design with the random-probabilistic selection of sampling locations within the boundaries of each stratum. Data generated within each stratum can be attributed to the dimensions of the stratum. Therefore, these data can be used to estimate the spatial extent of toxicity with a quantifiable degree of confidence (Heimbuch, et al., 1995). Strata boundaries were established to coincide with the dimensions of major basins, bays, inlets, waterways, etc. in which hydrographic, bathymetric and sedimentological conditions were expected to be relatively homogeneous (Figure 3a). Data from Ecology's SEDQUAL database were reviewed to assist in establishing strata boundaries.

The study area was subdivided into 32 irregular-shaped strata (Figure 3a-f). Large strata were established in the open waters of the area where toxicant concentrations were expected to be uniformly low (e.g., Admiralty Inlet, Puget Sound central basin). This approach provided the least intense sampling effort in areas known or suspected to be relatively homogeneous in sediment type and water depth, and relatively distant from contaminant sources. In contrast, relatively small strata were established in urban and industrial harbors nearer suspected sources in which conditions were expected to be heterogeneous or transitional (e.g., Elliott Bay, Eagle Harbor, Sinclair Inlet, and other basins west of Bainbridge Island). As a result, sampling effort was spatially more intense in the small strata than in the large strata. The large strata were roughly equivalent in size to each other as were the small strata to one another (Table 1). Areas with known topographic features which cannot be sampled with our methods (i.e., vanVeen grab sampler) were excluded from the strata design (e.g., the area between Useless Bay and Possession Sound (south of Whidbey Island), which was known to have rocky substrate).

Within the boundaries of each stratum, all possible latitude/longitude intersections had equal probabilities of being selected as a sampling location. The locations of individual sampling stations within each stratum were chosen randomly using GINPRO software developed by NOAA applied to digitized navigation charts. In most cases three samples were collected within each stratum; however, four stations were sampled in several strata expected to be heterogeneous in sediment quality. Four alternate locations were provided for each station in a numbered sequence. The coordinates for each alternate were provided in tables and were plotted on the appropriate navigation chart. In a few cases, the coordinates provided were inaccessible or only rocks and cobble were present at the location. In these cases, the first set of station coordinates was rejected and the vessel was moved to the next alternate. In the majority of the 100 stations, the first alternate location was sampled. Stratum 3 in Admiralty Inlet was abandoned when only rocks and cobble were encountered at all locations (Figure 3b). Final station coordinates are summarized in the navigation report (Appendix B).

Sample Collection

Sediments from 100 stations were collected during June 1998 with the 42' research vessel *Kittiwake*. Each station was sampled only once. Differential Global Positioning System (DGPS) with an accuracy of better than 5 meters was used to position the vessel at the station coordinates. The grab sampler was deployed and retrieved with a hydraulic winch.

Prior to sampling each station, all equipment used for toxicity testing and chemical analyses was washed with seawater, Alconox soap, acetone, and rinsed with seawater. Sediment samples were collected with a double 0.1 m^2, stainless steel, modified van Veen grab sampler. Sediment for toxicity testing and chemical analyses was collected simultaneously with sediment collected for the benthic community analyses to ensure synopticity of the data. Upon retrieval of the sampler, the contents were visually inspected to determine if the sample was acceptable (jaws closed, no washout, clear overlying water, sufficient depth of penetration). If the sample was unacceptable, it was dumped overboard at a location away from the station. If the sample was acceptable, information was recorded on station coordinates and the sediment color, odor, and type in field logs.

One 0.1 m^2 grab sample from one side of the sampler was collected for the benthic infaunal analyses. All infaunal samples were rinsed gently through nested 1.0 and 0.5 mm screens and the organisms retained on each screen were kept separate. Organisms were preserved in the field with a 10% aqueous solution of borax-buffered formalin.

From the other side of the sampler, sediment was removed for chemical and toxicity tests using a disposable, 2 mm deep, high-density polyethylene (HDPE) scoop. The top two to three cm of sediment was removed with the scoop and accumulated in a HDPE bucket. The sampler was deployed and retrieved from three to six times at each station, until a sufficient amount (about 7 l) of sediment was collected in the bucket. Between deployments of the grab, a teflon plate was placed upon the surface of the sample, and the bucket was covered with a plastic lid and to avoid contamination, oxidation, and photo-activation. After 7 l of sediment were collected, the sample was stirred with a stainless steel spoon to homogenize the sediments and then transferred to individual jars for the various toxicity tests and chemical analyses.

Precautions described above were taken to avoid contamination of the samples from engine exhaust, atmospheric particulates, and rain. A double volume sample was collected at five stations for duplicate chemical analyses. All samples were labeled and double-checked for station, stratum, and sample codes; sampling date; sampling time; and type of analysis to be performed.

Samples for chemical and toxicity tests were stored on deck in sealed containers placed in insulated coolers filled with ice. These samples were off-loaded from the research vessel every 1-3 days, and transported to the walk-in refrigerator at Ecology HQ building in Olympia. They were held there at 4°C until shipped on ice to either the NOAA contractors for toxicity tests or the Manchester Environmental Laboratory for chemical analyses by overnight courier. Chain of custody forms accompanied all sample shipments. After a minimum of 24 hours following collection and fixation, the benthic samples were rescreened (i.e., removed from formalin) and exchanged into 70% ethanol.

Laboratory Analyses

Toxicity Testing

Multiple toxicity tests were performed on aliquots of each sample to provide a weight of evidence. Tests were selected for which there were widely accepted protocols that would represent the toxicological conditions within different phases (partitions) of the sediments. The tests included those for amphipod survival in solid-phase (bulk) sediments, sea urchin fertilization success in pore waters, and microbial bioluminescence activity and cytochrome P450 HRGS induction in an organic solvent extract. Test endpoints, therefore, ranged from survival to level of physiological activity.

Amphipod Survival - Solid Phase

The amphipod tests are the most widely and frequently used assays in sediment evaluations performed in North America. They are performed with adult crustaceans exposed to relatively unaltered bulk sediments. *Ampelisca abdita* has shown relatively little sensitivity to nuisance factors such as grain size, ammonia, and organic carbon in previous surveys. In surveys performed by the NS&T Program (Long et al., 1996), this test has provided wide ranges in responses among samples, strong statistical associations with elevated toxicant levels, and small within-sample variability.

Ampelisca abdita is a euryhaline benthic amphipod that ranges from Newfoundland to south-central Florida, and along the eastern Gulf of Mexico. Also, it is abundant in San Francisco Bay along the Pacific coast. The amphipod test with *A. abdita* has been routinely used for sediment toxicity tests in support of numerous EPA programs, including the Environmental Monitoring and Assessment Program (EMAP) in the Virginian, Louisianian, Californian, and Carolinian provinces (Schimmel et al., 1994).

Amphipod survival tests were conducted by Science Applications International Corporation (SAIC), in Narragansett, R.I. All tests were initiated within 10 days of the date samples were collected. Samples were shipped by overnight courier in one-gallon high-density polyethylene jugs which had been washed, acid-stripped, and rinsed with de-ionized water. Sample jugs were packed in shipping coolers with blue ice. Each was inspected to ensure they were within acceptable temperature limits upon arrival and stored at 4°C until testing was initiated. Prior to testing, sediments were mixed with a stainless steel paddle and press-sieved through a 1.0 mm mesh sieve to remove debris, stones, resident biota, etc.

Amphipods were collected by SAIC from tidal flats in the Pettaquamscutt (Narrow) River, a small estuary flowing into Narragansett Bay, RI. Animals were held in the laboratory in pre-sieved uncontaminated ("home") sediments under static conditions. Fifty percent of the water in the holding containers was replaced every second day when the amphipods were fed. During holding, *A. abdita* were fed laboratory-cultured diatoms (*Phaeodactylum tricornutum*). Negative control sediments were collected by SAIC from the Central Long Island Sound (CLIS) reference station of the U.S Army Corps of Engineers, New England Division. These sediments have been tested repeatedly with the amphipod survival test and other assays and found to be non-toxic (amphipod survival has exceeded 90% in 85% of the tests) and un-contaminated (Long et al., 1996). Sub-samples of the CLIS sediments were tested along with each series of samples from northern Puget Sound.

Amphipod testing followed the procedures detailed in the Standard Guide for conducting 10 day Static Sediment Toxicity Tests with Marine and Estuarine Amphipods (ASTM, 1993). Briefly, amphipods were exposed to test and negative control sediments for 10 days with 5 replicates of 20 animals each under static conditions using filtered seawater. Aliquots of 200 ml of test or control sediments were placed in the bottom of the one-liter test chambers, and covered with approximately 600 ml of filtered seawater (28-30 ppt). Air was provided by air pumps and delivered into the water column through a pipette to ensure acceptable oxygen concentrations, but suspended in a manner to ensure that the sediments would not be disturbed.

Temperature was maintained at ~20°C by a temperature-controlled water bath. Lighting was continuous during the 10-day exposure period to inhibit the swimming behavior of the amphipods. Constant light inhibits emergence of the organisms from the sediment, thereby maximizing the amphipod's exposure to the test sediments. Information on temperature, salinity, dissolved oxygen, pH and ammonia in test chambers was obtained during tests of each batch of samples to ensure compliance within acceptable ranges. Ammonia concentrations were determined in both pore waters (day 0 of the tests) and overlying waters (days 2 and 8 of the tests). Concentrations of the un-ionized form of ammonia were calculated, based upon measures of total ammonia, and concurrent measures of pH, salinity and temperature.

Twenty healthy, active animals were placed into each test chamber, and monitored to ensure they burrowed into sediments. Non-burrowing animals were replaced, and the test initiated. The jars were checked daily, and records were kept of animals that had died, were on the water surface, had emerged on the sediment surface, or were in the water column. Animals on the water surface were gently freed from the surface film to enable them to burrow, and dead amphipods were removed.

Tests were terminated after ten days. Contents of each of the test chambers were sieved through a 0.5 mm mesh screen. The animals and any other material retained on the screen were examined under a stereomicroscope for the presence of amphipods. Total amphipod mortality was recorded for each test replicate.

A positive control (reference toxicant) test was used to document the sensitivity of each batch of test organisms. The positive control consisted of 96 hr water-only exposures to sodium dodecyl sulfate (SDS). The LC50 (lethal concentration for 50% of the test animals) values were calculated for each test run with results from tests of five SDS concentrations.

Sea Urchin Fertilization - Pore Water

Tests of sea urchin fertilization have been used in assessments of ambient water and effluents and in previous NS&T Program surveys of sediment toxicity (Long et al., 1996). Test results have shown wide ranges in responses among test samples, excellent within-sample homogeneity, and strong associations with the concentrations of toxicants in the sediments. This test combines the features of testing sediment pore waters (the phase of sediments in which dissolved toxicants are highly bioavailable) and exposures to early life stages of invertebrates (sperm cells) which often are more sensitive than adult forms. Tests of sediment pore water toxicity were conducted with the Pacific coast purple urchin *Strongylcentrotus purpuratus* by the U.S. Geological Survey laboratory in Corpus Christi, Texas.

Sediments from each sampling location were shipped by overnight courier in one-gallon high-density polyethylene jugs chilled in insulated coolers packed with blue ice. Upon arrival at the laboratory, samples were either refrigerated at 4°C or processed immediately. All samples were processed (i.e., pore waters extracted) within 10 days of the sampling date.

Pore waters were extracted within ten days of the date of collection, usually within 2-4 days. Pore water was extracted from sediments with a pressurized squeeze extraction device (Carr and Chapman, 1995). After extraction, pore water samples were centrifuged in polycarbonate bottles (at 1200 G for 20 minutes) to remove any particulate matter. The supernatant was then frozen at -20°C. Two days before the start of a toxicity test, samples were moved from a freezer to a refrigerator at 4°C, and one day prior to testing, thawed in a tepid (20°C) water bath. Experiments performed by USGS have demonstrated no effects upon toxicity attributable to freezing and thawing of the pore water samples (Carr and Chapma, 1995).

Tests followed the methods of Carr and Chapman (1995); Carr et al. (1996a,b); Carr (1998) and USGS SOP F10.6, developed initially for *Arbacia punctulata*, but adapted for use with *S. purpuratus*. Unlike *A. punctulata*, adult *S. purpuratus* cannot be induced to spawn with electric stimulus. Therefore, spawning was induced by injecting 1-3 ml of 0.5 M potassium chloride into the coelomic cavity. Tests with *S. purpuratus* were conducted at 15°C; test temperatures were maintained by incubation of the pore waters, the dilution waters and the tests themselves in an environmental chamber. Adult *S. purpuratus* were obtained from Marinus Corporation, Long Beach, CA. Pore water from sediments collected in Redfish Bay, Texas, an area located near the testing facility, were used as negative controls. Sediment pore waters from this location have been determined repeatedly to be non-toxic in this test in many trials (Long et al., 1996). Each of the pore water samples was tested in a dilution series of 100%, 50%, and 25% of the water quality (salinity)-adjusted sample with 5 replicates per treatment. Dilutions were made with clean, filtered (0.45 *u*m), Port Aransas laboratory seawater, which has been shown in many previous trials to be non-toxic. A dilution series test with SDS was included as a positive control.

Sample temperatures were maintained at 20±1°C. Sample salinity was measured and adjusted to 30±1 ppt, if necessary, using purified deionized water or concentrated brine. Other water quality measurements were made for dissolved oxygen, pH, sulfide and total ammonia. Temperature and dissolved oxygen were measured with YSI meters; salinity was measured with Reichert or American Optical refractometers; pH, sulfide and total ammonia (expressed as total ammonia nitrogen, TAN) were measured with Orion meters and their respective probes. The concentrations of un-ionized ammonia (UAN) were calculated using respective TAN, salinity, temperature, and pH values.

For the sea urchin fertilization test, the samples were cooled to 15±1°C. Fifty µl of appropriately diluted sperm were added to each vial, and incubated at 15±1°C for 30 minutes. One ml of a well-mixed dilute egg suspension was added to each vial, and incubated an additional 30 minutes at 15± 2°C. Two ml of a 10% solution of buffered formalin was added to stop the test. Fertilization membranes were counted, and fertilization percentages calculated for each replicate test.

The relative sensitivities of *S. purpuratus* and *A. punctulata* were determined as a part of the 1997 northern Puget Sound survey (Long et al., 1999a). A series of five reference toxicant tests were performed with both species. Tests were conducted with copper sulfate, PCB aroclor 1254, o,p'-DDD, phenanthrene, and naphthalene in seawater. The data indicated that the two species generally were similar in their sensitivities to the five selected chemicals.

Microbial Bioluminescence (Microtox™) - Organic Solvent Extract

This is a test of the relative toxicity of extracts of the sediments prepared with an organic solvent, and, therefore, it is unaffected by the effects of environmental factors, such as grain size, ammonia and organic carbon. Organic toxicants, and to a lesser degree trace metals, that may or may not be readily bioavailable are extracted with the organic solvent. Therefore, this test can be considered as indicative of the potential toxicity of mixtures of substances bound to the sediment matrices. In previous NS&T Program surveys, the results of Microtox™ tests have shown extremely high correlations with the concentrations of mixtures of organic compounds. Microtox™ tests were run by the U. S. Geological Survey Laboratory in Columbia, MO, on extracts prepared by Columbia Analytical Services (CAS) in Kelso, WA.

The Microtox™ assay was performed with dichloromethane (DCM) extracts of sediments following the basic procedures used in testing Puget Sound sediments (PSEP, 1995) and Pensacola Bay sediments (Johnson and Long, 1998). All sediment samples were stored in the dark at 4°C for 5-10 days before processing was initiated. A 3-4 g sediment sample from each station was weighed, recorded, and placed into a DCM-rinsed 50 ml centrifuge tube. A 15 g portion of sodium sulfate was added to each sample and mixed. Pesticide grade DCM (30 ml) was added and mixed. The mixture was shaken for 10 seconds, vented and tumbled overnight.

Sediment samples were allowed to warm to room temperature and the overlying water discarded. Samples were then homogenized with a stainless steel spatula, and 15-25 g of sediment were transferred to a centrifuge tube. The tubes were spun at 1000 G for 5 minutes and the pore water was removed using a Pasteur pipette. Three replicate 3-4 g sediment subsamples from each station were placed in mortars containing a 15g portion of sodium sulfate and mixed. After 30 minutes, subsamples were ground with a pestle until dry. Subsamples were added to 50 ml centrifuge tubes and 30 ml of DCM were added to each tube and shaken to dislodge sediments. Tubes were shaken overnight on an orbital shaker at a moderate speed and then centrifuged at 500 G for 5 min and the sediment extracts transferred to Turbovap™ tubes. Then, 20 ml of DCM was added to sediment, shaken by hand for 10 seconds and spun at 500 g for 5 minutes. The previous step was repeated once more and all three extracts were combined in the Turbovap™ tube. Sample extracts were then placed in the Turbovap™ and reduced to a volume of 0.5 ml. The sides of the Turbovap™ tubes were rinsed down with methylene chloride and again reduced to 0.5 ml. Then, 2.5 ml of dimethylsulfoxide (DMSO) were added to the tubes that were returned to the Turbovap™ for an additional 15 minutes. Sample extracts were placed in clean vials and 2.5 ml of DMSO were added to obtain a final volume of 5 ml DMSO. Because organic sediment extracts were obtained with DCM, a strong non-polar solvent, the final extract was evaporated and redissolved in DMSO. The DMSO was compatible with the Microtox™ system because of its low test toxicity and good solubility with a broad spectrum of apolar chemicals (Johnson and Long, 1998).

A suspension of luminescent bacteria, *Vibrio fischeri* (Azur Environmental, Inc.), was thawed and hydrated with toxicant-free distilled water, covered and stored in a 4°C well on the Microtox™ analyzer. An aliquot of 10 µl of the bacterial suspension was transferred to a test vial containing the standard diluent (2% sodium chloride (NaCl)) and equilibrated to 15°C using a temperature-controlled photometer. The amount of light lost per sample was assumed to be proportional to the toxicity of that test sample. To determine toxicity, each sample was diluted into four test concentrations. Percent decrease in luminescence of each cuvette relative to the reagent blank was calculated. Light loss was expressed as a gamma value and defined as the ratio of light lost to light remaining. The log of gamma values from these four dilutions was plotted and compared with the log of the samples' concentrations. The concentrations of the extract that inhibited luminescence by 50% after a 5-min exposure period, the EC50 value, was determined and expressed as mg equivalent sediment wet weight. Data were reduced using the Microtox™ Data Reduction software package. All EC50 values were average 5 minutes readings with 95% confidence intervals for three replicates.

A negative control (extraction blank) was prepared using DMSO, the test carrier solvent. A phenol standard (45mg/l phenol) was run after re-constitution of each vial of freeze-dried *V. fischeri*. Tests of extracts of sediments from the Redfish Bay, TX site used in the urchin tests also were used as negative controls in the Microtox™ tests.

Human Reporter Gene System (Cytochrome P450) Response - Organic Solvent Extract

Sediment samples were also analyzed with the Human Reporter Gene System (cytochrome P450) response assay (P450 HRGS). This test is used to determine the presence of organic compounds that bind to the Ah (aryl hydrocarbon) receptor and induce the CYP1A locus on the vertebrate chromosome. Under appropriate test conditions, induction of CYP1A is evidence that the cells have been exposed to one or more of these xenobiotic organic compounds, including dioxins, furans, planar PCBs, and several polycyclic aromatic hydrocarbons (Jones and Anderson, 1999). Differences in the ability of the P450 enzyme to metabolize chlorinated and non-chlorinated compounds allow for differentiation between these classes of compounds in environmental samples. Since most PAHs are rapidly metabolized, they exhibit a maximum response in 6 hours, at which point the response begins to fade. Chlorinated hydrocarbons (dioxins, furans, and certain PCBs), on the other hand, do not show a maximum response until 16 hours after exposure (Jones and Anderson, 2000). The P450 HRGS assay provides an estimate of the presence of contaminants bound to sediment that could produce chronic and/or carcinogenic effects in benthic biota and/or demersal fishes that feed in sediments. These tests were run by the Columbia Analytical Services, Inc. in Vista, CA with solvent extracts prepared by their laboratory in Kelso, WA.

The details of this test are provided as U.S. EPA Method 4425 (EPA, 1999), Standard Method 8070 by the American Public Health Association (APHA, 1998), and ASTM method E 1853M-98 by the American Society for Testing and Material (ASTM, 1999). The test uses a transgenic cell line (101L), derived from the human hepatoma cell line (HepG2), in which the flanking sequences of the CYP1A gene, containing the xenobiotic response elements (XREs), have been stably linked to the firefly luciferase gene (Anderson et al. 1995, 1996). As a result, the enzyme luciferase is produced in the presence of compounds that bind the XREs.

After removal of debris and pebbles, the sediment sample was homogenized, dried with anhydrous sodium sulfate, and 20 g of sediment was extracted by sonication with dichloromethane (DCM), also known as methylene chloride. The extract was carefully evaporated and concentration under a flow of nitrogen, and exchanged into mixture of dimethylsulfoxide (DMSO), toluene and isopropyl alcohol (2:1:1) to achieve a final volume of 2 mL. The 2 mL extracts were split into two 1 mL vials for testing with the Microtox and P450 HRGS assays. The extraction procedure is well suited for extraction of neutral, non-ionic organic compounds, such as aromatic and chlorinated hydrocarbons. Extraction of other classes of toxicants, such as metals and polar organic compounds, is not efficient. DMSO is compatible with these tests because of its low toxicity and high solubility with a broad spectrum of non-polar chemicals.

Briefly, a small amount of organic extract of sediment (up to 20 μL), was applied to approximately one million cells in each well of a 6-well plate with 2 mL of medium. Detection of enzyme induction in this assay is relatively rapid and simple to measure since binding of a xenobiotic with the Ah receptor results in the production of luciferase.

After 16 hours of incubation with the extract, the cells are washed and lysed. Cell lysates are centrifuged, and the supernatant is mixed with buffering chemicals. Enzyme reaction is initiated by injection of luciferin. The resulting luminescence is measured with a luminometer and is expressed in relative light units (RLUs). A solvent blank (using a volume of solvent equal to the sample's volume being tested) and reference toxicants (TCDD, dioxin/furan mixture, B[a]P) are used with each batch of samples.

Mean RLU, standard deviation, and coefficient of variation of replicate analyses of each test solution are recorded. Enzyme fold induction (times background) is calculated as the mean RLU of the test solution divided by the mean RLU of the solvent blank. From the standard concentration-response curve for benzo[a]pyrene (B[a]P), the HRGS response to 1 µg/mL is approximately 60. Data are converted to µg of B[a]P equivalents per g of sediment by considering the dry weight of the samples, the volume of solvent, the amount added to the well, and the factor of 60 for B[a]P. If 20 µL of the 2 mL extracts are used, then fold induction is multiplied by the volume factor of 100 and divided by 60 times the dry weight. Since testing at only one time interval (16 h) will not allow discrimination between PAHs and chlorinated hydrocarbons, the data are also expressed as Toxic Equivalents (TEQs). Based on a standard curve with a dioxin/furan mixture, fold induction is equal to the TEQ (in pg/mL). Therefore, fold induction is multiplied by the volume factor (e.g., 100), and divided by the dry weight times 1000 to convert pg to the TEQ in ng/g.

Quality control tests are run with clean extracts spiked with tetrachlorodibenzo-p-dioxin (TCDD) and B[a]P to ensure compliance with results of previous tests. From a long-term control chart, the running average fold induction for 1 ng/mL of dioxin is approximately 105, and fold induction for 1 µg/mL of B[a]P is 60. Tests are rerun if the coefficient of variation for replicates is greater than 20%, and if fold induction is over the linear range (100 fold). HRGS tests performed on extracts from Redfish Bay, Texas, are used as a negative control.

For a given study area, the B[a]P equivalent data are used to calculate the mean, standard deviation and 99% confidence interval for all samples (Anderson et al., 1999a). Samples above the 99% confidence interval are generally considered to pose some chronic threat to benthic organisms. The values from one investigation are compared to the overall database to evaluate the magnitude of observed concentration. From analysis of the database, values less than 11 µg/g B[a]P equivalents (B[a]PEq) are not likely to produce adverse effects, while impacts are uncertain between 11 and 37 µg B[a]PEq/g. Moderate effects are expected at 37 µg/g, and sediment with over 60 µg B[a]PEq/g have been shown to be highly correlated with degraded benthic communities (Fairey, et al., 1996). Previous studies have shown a high correlation of the HRGS responses to extracts of sediments and tissues to the content of PAHs in the samples (Anderson et al. 1999a, 1999b).

In a few samples from Elliott Bay in which enzyme induction responses were relatively high, analyses were conducted after both 6 and 16 hours of exposure. Because PAHs produce peak responses at 6 hours, while chlorinated compounds produce a maximum response at 16 hours, the ratio of the two responses allows a quick estimation of the primary contaminant type in the samples. Five of these samples were analyzed, in addition, for PCB congeners by EPA method 8082 and for polynuclear aromatic hydrocarbon (PAH) compounds by GC/MS SIM method.

Chemical Analyses

Laboratory analyses were performed for 157 parameters and chemical compounds (Table 2), including 133 trace metals, pesticides, hydrocarbons and selected normalizers (i.e., grain size, total organic carbon) that are routinely quantified by the NS&T Program. An additional 20 compounds were required by Ecology to ensure comparability with previous PSAMP and enforcement studies. Seven additional compounds were automatically quantified by Manchester Environmental Laboratory during analysis for the required compounds. Analytical procedures provided performance equivalent to those of the NS&T Program and the PSEP Protocols, including those for analyses of blanks and standard reference materials. Information was reported on recovery of spiked blanks, analytical precision with standard reference materials, and duplicate analyses of every 20th sample.

The laboratory analytical methods and reporting limits for quantitation of the 157 chemistry parameters analyzed for are summarized in Table 3 and described in detail below. Methods and resolution levels for field collection of temperature and salinity are included in Table 4.

Grain Size

Analysis for grain size was performed according to the PSEP Protocols (PSEP, 1986). The PSEP grain size method is a sieve-pipette method. In this method, the sample is passed through a series of progressively smaller sieves, with each fraction being weighed. After this separation, the very fine material remaining is placed into a column of water, and allowed to settle. Aliquots are removed at measured intervals, and the amount of material in each settling fraction is measured. This parameter was contracted by Manchester to Hart Crowser, Seattle, Washington.

Total Organic Carbon (TOC)

Total organic carbon analysis was performed according to PSEP Protocols (PSEP, 1986). The method involves drying sediment material, pretreatment and subsequent oxidation of the dried sediment, and determination of CO_2 by infra-red spectroscopy.

Metals

To maintain compatibility with previous PSAMP metals data, EPA Methods 3050/6010 were used for the determination of metals in sediment. Method 3050 is a strong acid (aqua regia) digest that has been used for the last several years by Ecology for the characterization of sediments for trace metal contamination. Method 3050 is also the recommended digestion technique for digestion of sediments in the recently revised PSEP protocols (PSEP, 1996c). This digestion does not yield geologic (total) recoveries for most analytes including silicon, iron, aluminum and manganese. It does, however, recover quantitatively most anthropogenic metals contamination and deposition.

For comparison with NOAA's national bioeffects survey's existing database, Manchester simultaneously performed a total (hydrofluoric acid-based) digestion (EPA method 3052) on portions of the same samples. Determination of metals values for both sets of extracts were made via ICP, ICP-MS, or GFAA, using a variety of EPA methods (Table 3) depending upon the appropriateness of the technique for each analyte.

Mercury

Mercury was determined by USEPA Method 245.5, mercury in sediment by cold vapor atomic absorption (CVAA). The method consists of a strong acid sediment digestion, followed by reduction of ionic mercury to Hg^0, and analysis of mercury by cold vapor atomic absorption.

This method is recommended by the PSEP Protocols (PSEP, 1996c) for the determination of mercury in Puget Sound sediment.

Butyl Tins

Butyl tins in sediments were analyzed by the Manchester method (Manchester Environmental Laboratory, 1997). This method consists of solvent extraction of sediment, derivitization of the extract with the Grignard reagent hexylmagnesium bromide, cleanup with silica and alumina, and analysis by Atomic Emission Detector (AED).

Base/Neutral/Acid (BNA) Organic Compounds

USEPA Method 846 8270, a recommended PSEP method (PSEP, 1996d), was used for semi-volatile analysis. This is a capillary column, GC/MS method.

Polynuclear Aromatic Hydrocarbons (PAH) (extended list)

At NOAA's request, the extended analyte list was modified by the inclusion of additional PAH compounds. The PAH analytes were extracted separately using the EPA method SW846 3545. This method uses a capillary column GC/MS system set up in selective ion monitoring (SIM) mode to quantify PAHs. Quantitation is performed using an isotopic dilution method modeled after USEPA Method SW 846 8270, referenced in PSEP, 1996d.

Chlorinated Pesticides and Polychlorinated Biphenyl (PCB) Aroclors

EPA Method 8081 for chlorinated pesticides and PCB was used for the analysis of these compounds. This method is a GC method with dual dissimilar column confirmation. Electron capture detectors were used.

PCB Congeners

PCB methodology was based on the NOAA congener methods detailed in Volume IV of the NS&T Sampling and Analytical Methods documents (Lauenstein and Cantillo, 1993). The concentrations of the standard NOAA list of 20 congeners were determined.

Benthic Community Analyses

Sample Processing and Sorting

All methods, procedures, and documentation (chain-of-custody forms, tracking logs, and data sheets) were similar to those described for the PSEP (1987) and in the PSAMP Marine Sediment Monitoring Component – Final Quality Assurance Project and Implementation Plan (Dutch et al., 1998).

Upon completion of field collection, benthic infaunal samples were checked into the benthic laboratory at Ecology's headquarters building. After a minimum fixation period of 24 hours (and maximum of 7-10 days), the samples were washed on sieves to remove the formalin (1.0 mm fraction on a 0.5 mm sieve, 0.5 mm fraction on a 0.25 mm sieve) and transferred to 70% ethanol. Sorting and taxonomic identification of the 0.5 mm fraction will be completed separately by a NOAA contractor outside of the scope of work of this effort. The results of these separate analyses will be reported elsewhere by NOAA. After staining with rose bengal, the 1.0 mm sample fractions were examined under dissection microscopes, and all macroinfaunal invertebrates and fragments were removed and sorted into the following major taxonomic groups: Annelida, Arthropoda, Mollusca, Echinodermata, and miscellaneous taxa. Meiofaunal organisms such as nematodes and foraminiferans were not removed from samples, although their presence and relative abundance were recorded. Representative samples of colonial organisms such as hydrozoans, sponges, and bryozoans were collected, and their relative abundance noted. Sorting QA/QC procedures consisted of resorting 25% of each sample by a second sorter to determine whether a sample sorting efficiency of 95% removal was met. If the 95% removal criterion was not met, the entire sample was resorted.

Taxonomic Identification

Upon completion of sorting and sorting QA/QC, the majority of the taxonomic work was contracted to recognized regional taxonomic specialists. Organisms were enumerated and identified to the lowest taxonomic level possible, generally to species. In general, anterior ends of organisms were counted, except for bivalves (hinges), gastropods (opercula), and ophiuroids (oral disks). When possible, at least two pieces of literature (preferably including original descriptions) were used for each species identification. A maximum of three representative organisms of each species or taxon was removed from the samples and placed in a voucher collection. Taxonomic identification quality control for all taxonomists included re-identification of 5% of all samples identified by the primary taxonomist and verification of voucher specimens generated by another qualified taxonomist.

Data Summary, Display, and Statistical Analysis

Toxicity Testing

Amphipod Survival – Solid Phase

Data from each station in which mean percent survival was less than that of the control were compared to the CLIS control using a one-way, unpaired t-test (alpha < 0.05) assuming unequal variance. Results were not transformed because examination of data from previous tests has shown that results of tests performed with *A. abdita* met the requirements for normality.

"Significant toxicity" for *A. abdita* is defined here as survival statistically less than that in the performance control (alpha < 0.05). In addition, samples in which survival was significantly less than controls and less than 80% of CLIS control values were regarded as “highly toxic”. The 80% criterion is based upon statistical power curves created from SAIC's extensive testing database with *A. abdita* (Thursby et al., 1997). Their analyses showed that the power to detect a 20% difference from the control is approximately 90%. The minimum significant difference (i.e., “MSD” of <80% of control response) was used as the critical value in calculations of the spatial extent of toxicity (Long et al., 1996, 1999a).

Sea Urchin Fertilization - Pore Water

For the sea urchin fertilization tests, statistical comparisons among treatments were made using ANOVA and Dunnett's one-tailed *t*-test (which controls the experiment-wise error rate) on the arcsine square root transformed data with the aid of SAS (SAS, 1989). The trimmed Spearman-Karber method (Hamilton et al., 1977) with Abbott's correction (Morgan, 1992) was used to calculate EC50 (50% effective concentration) values for dilution series tests. Prior to statistical analyses, the transformed data sets were screened for outliers (Moser and Stevens, 1992). Outliers were detected by comparing the studentized residuals to a critical value from a t-distribution chosen using a Bonferroni-type adjustment. The adjustment is based on the number of observations (n) so that the overall probability of a type 1 error is at most 5%. The critical value (CV) is given by the following equation: $cv= t(df_{Error}, .05/[2 \times n])$. After omitting outliers but prior to further analyses, the transformed data sets were tested for normality and for homogeneity of variance using SAS/LAB Software (SAS, 1992). Statistical comparisons were made with mean results from the Redfish Bay controls. Reference toxicant concentration results were compared to filtered seawater controls and each other using both Dunnett's t-test and Duncan's multiple range test to determine lowest observable effects concentrations (LOECs) and no observable effects concentrations (NOECs).

In addition to the Dunnett's one-tailed t-tests, data from field-collected samples were treated with an analysis similar to the MSD analysis used in the amphipod tests. Power analyses of the sea urchin fertilization data have shown MSDs of 15.5% for alpha <0.05 and 19% for alpha <0.01. However, to be consistent with the statistical methods used in previous surveys (Long et al., 1996, 1999a), estimates of the spatial extent of toxicity were based upon the same critical value used in the amphipod tests (i.e., <80% of control response).

Microbial Bioluminescence (Microtox™) - Organic Solvent Extract

Microtox™ data were analyzed using the computer software package developed by Microbics Corporation to determine concentrations of the extract that inhibit luminescence by 50% (EC50). This value was then converted to mg dry weight using the calculated dry weight of sediment present in the original extract. To determine significant differences of samples from each station, pair-wise comparisons were made between survey samples and results from Redfish Bay control sediments using analysis of variance (ANOVA). Concentrations tested were expressed as mg dry weight based on the percentage extract in the 1 ml exposure volume and the calculated dry weight of the extracted sediment. Statistical comparisons among treatments were made using ANOVA and Dunnett's one-tailed t-tests on the log transformed data with the aid of SAS (SAS, 1989).

Three critical values were used to estimate the spatial extent of toxicity in these tests. First, a value of <80% of Redfish Bay controls (equal to 8.5 mg/ml) was used; i.e., equivalent to the values used with the amphipod and urchin tests. Second and third, values of <0.51 mg/ml and <0.06 mg/ml calculated in the 1997 northern Puget Sound study were used, based upon the frequency distribution of Microtox™ data from NOAA's surveys nationwide (as per Long et al., 1999a).

Human Reporter Gene System (Cytochrome P450) Response - Organic Solvent Extract

Microsoft Excel 5.0 was used to determine the mean RGS response and the 99% confidence interval of the B[a]P equivalent values for all 100 samples. Mean responses determined for all

100 samples were compared to the upper prediction limits calculated in the 1997 northern Puget Sound study (Long et al., 1999a): >11.1 µg/g and >37.1 µg/g.

Incidence and Severity, Spatial Patterns and Gradients, and Spatial Extent of Sediment Toxicity

The incidence of toxicity was determined by dividing the numbers of samples identified as either significantly different from controls (i.e., "significantly toxic") or significantly different from controls and <80% of control response (i.e., “highly toxic”) by the total number of samples tested (i.e., 100). Severity of the responses was determined by examining the range in responses for each of the tests and identifying those samples with the highest and lowest responses. Spatial patterns in toxicity were illustrated by plotting the results for each sampling station as symbols or histograms on base maps of each major region.

Estimates of the spatial extent of toxicity were determined with cumulative distribution functions in which the toxicity results from each station were weighted to the dimensions (km^2) of the sampling stratum in which the samples were collected (Schimmel et al., 1994). The size of each stratum (km^2) was determined by use of an electronic planimeter applied to navigation charts, upon which the boundaries of each stratum were outlined (Table 1). Stratum sizes were calculated as the averages of three trial planimeter measurements that were all within 10% of each other. A critical value of less than 80% of control response was used in the calculations of the spatial extent of toxicity for all tests except the cytochrome P450 HRGS assay. That is, the sample-weighted sizes of each stratum in which toxicity test results were less than 80% of control responses were summed to estimate the spatial extent of toxicity. Additional critical values described above were applied to the Microtox™ and cytochrome P450 HRGS results.

Concordance Among Toxicity Tests

Non-parametric, Spearman-rank correlations were determined for combinations of toxicity test results to quantify the degree to which these tests showed correspondence in spatial patterns in toxicity. None of the data from the four toxicity tests were normally distributed, therefore, non-parametric tests were used on raw (i.e., nontransformed) data. Both the correlation coefficients (rho) and the probability (p) values were calculated.

Chemical Analyses

Spatial Patterns and Spatial Extent of Sediment Contamination

Chemical data from the sample analyses were plotted on base maps to identify spatial patterns, if any, in concentrations. The results were shown with symbols indicative of samples in which effects-based numerical guideline concentrations were exceeded. The spatial extent of contamination was determined with cumulative distribution functions in which the sizes of strata in which samples exceeded effects-based, numerical guidelines were summed.

Three sets of chemical concentrations were used as critical values: the SQS and CSL values contained in the Washington State Sediment Management Standards (Chapter 173-204 WAC) and the Effects Range-Median (ERM) values developed by Long et al. (1995) from NOAA’s national sediment data base. Two additional measures of chemical contamination also examined and considered for each sample were the Effects Range-Low (ERL) values developed for NOAA (Long et al., 1995), and the mean ERM quotient (Long and MacDonald, 1998). Samples with chemical concentrations greater than ERLs were viewed as slightly contaminated as opposed to those with concentrations less than or equal to the ERLs, which were viewed as uncontaminated. Mean ERM quotients were calculated as the mean of the quotients derived by dividing the chemical concentrations in the samples by their respective ERM values. The greater the mean ERM quotient, the greater the overall contamination of the sample as determined by the concentration of 25 substances. Mean ERM quotient values of 1.0 or greater, equivalent to ERM unity, were independently determined to be highly predictive of acute toxicity in amphipod survival tests (Long and MacDonald, 1998). Mean SQS and CSL quotients were determined using the same procedure.

Chemistry/Toxicity Relationships

Chemistry/toxicity relationships were determined in a multi-step sequence. First, the concentrations of different groups of chemicals were normalized to their respective ERM values (Long et al., 1995) and to their Washington State SQS and CSL values (Washington State Sediment Management Standards – Ch. 173-204 WAC), generating mean ERM, SQS, and CSL quotients. Non-parametric, Spearman-rank correlations were then used to determine if there were relationships between the four measures of toxicity and these normalized mean values generated for the different groups of chemical compounds.

Second, Spearman-rank correlations were also used to determine relationships between each toxicity test and each physical/chemical variable. The correlation coefficients and their statistical significance (p values) were recorded and compared among chemicals to identify which chemicals co-varied with toxicity and which did not. For many of the different semivolatile organic substances in the sediments, correlations were conducted for all 100 samples, using the limits of quantitation for values reported as undetected. If the majority of concentrations were qualified as either estimates or below quantitation limits, the correlations were run again after eliminating those samples. No analyses were performed for the numerous chemicals whose concentrations were below the limits of quantitation in all samples.

Third, for those chemicals in which a significant correlation was observed, the data were examined in scatterplots to determine whether there was a reasonable pattern of increasing toxicity with increasing chemical concentration. Also, chemical concentrations in the scatterplots were compared with the SQS, CSL, and ERM values to determine which samples, if any, were both toxic and had elevated chemical concentrations. The concentrations of un-ionized ammonia were compared to lowest observable effects concentrations (LOEC) determined for the sea urchin tests by the USGS (Carr et al., 1995) and no observable effects concentrations (NOEC) determined for amphipod survival tests (Kohn et al., 1994).

The objectives of this study did not include a determination of the cause(s) of toxicity or benthic alterations. Such determinations would require the performance of toxicity identification evaluations and other similar research. The purpose of the multi-step approach used in the study was to identify which chemicals, if any, showed the strongest concordance with the measures of toxicity and benthic infaunal structure.

Correlations were determined for all the substances that were quantified, including trace metals (both total and partial digestion), metalloids, un-ionized ammonia (UAN), percent fines, total organic carbon (TOC), chlorinated organic hydrocarbons (COHs), and polynuclear aromatic hydrocarbons (PAHs). Concentrations were normalized to TOC where required for SQS and CSL values.

Those substances that showed significant correlations were indicated with asterisks (*= $p \leq 0.05$, ** = $p \leq 0.01$, ***= $p \leq 0.001$, and ****= $p \leq 0.0001$) depending upon the level of probability. A Bonferroni's adjustment was performed to account for the large number of independent variables (157 chemical compounds). This adjustment is required to eliminate the possibility of some correlations appearing to be significant by random chance alone.

Benthic Community Analyses

All benthic infaunal data were reviewed and standardized for any taxonomic nomenclatural inconsistencies by Ecology personnel using an internally developed standardization process. With assistance from the taxonomists, the final species list was also reexamined for identification and removal of taxa that were non-countable infauna. This included (1) organisms recorded with presence/absence data, such as colonial species, (2) meiofaunal organisms, and (3) incidental taxa that were caught by the grab, but are not a part of the infauna (e.g., planktonic forms).

A series of benthic infaunal indices were then calculated to summarize the raw data and characterize the infaunal invertebrate assemblages identified from each station. Indices were based upon all countable taxa, excluding colonial forms. Five indices were calculated, including total abundance, major taxa abundance, taxa richness, Pielou’s evenness (J’), and Swartz’s Dominance Index (SDI). These indices are defined in Table 5.

Benthic Community/Chemistry and Benthic Community/Toxicity Analyses

Nonparametric Spearman-rank correlation analyses were conducted among all benthic indices, chemistry, and toxicity data. The correlation coefficients (rho values) and their statistical significance (p values) were recorded and examined to identify which benthic indices co-varied with toxicity results and chemistry concentrations. Comparisons were made to determine similarities between these correlation results and those generated for the chemistry/toxicity correlation analyses.

Sediment Quality Triad Analyses

Following the suggestions of Chapman (1996), summarized data from the chemical analyses, toxicity tests, and benthic analyses were compiled to identify the sampling locations with the highest and lowest overall sediment quality and samples with mixed or intermediate results. The percent spatial extent of sediment quality was computed for stations with four combinations of chemical/toxicity/benthic results. Highest quality sediments were those in which no chemical concentrations exceeded numerical guidelines, toxicity was not apparent in any of the tests, and the benthos included relatively large numbers of organisms and species, and pollution-sensitive species were present. Lowest quality sediments were those with chemical concentrations greater than the guidelines, toxicity in at least one of the tests, and a relatively depauperate benthos.

The benthic data analyses and interpretations presented in this report are intended to be preliminary and general. Estimates of the spatial extent of benthic alterations are not made due to absence of a widely accepted critical value at this time. A more thorough examination of the benthic infauna communities in central Puget Sound and their relationship to sediment characteristics, toxicity, and chemistry will be presented in future reports.

Results

A record of all field notes and observations made for each sediment sample collected is presented in Appendix C. The results of the toxicity testing, chemical analyses, and benthic infaunal abundance determination are reported in various summarized tables in this section of the report and in the appendices. Due to the large volume of data generated, not all raw data has been included in this report. All raw data can be obtained from Ecology's Sediment Monitoring Team database or Ecology's Sediment Management Unit SEDQUAL database. The web site addresses linking to both these databases are located on the inside cover of this report.

Toxicity Testing

Incidence and Severity of Toxicity

Amphipod Survival - Solid Phase

Tests were performed in 13 batches that coincided with shipments from the field crew. Tests on all samples were initiated within 10 days of the date they were collected. Amphipods ranged in size from 0.5 to 1.0 mm, test temperatures ranged from 19°C to 20.2°C, and mean percent survival in CLIS controls ranged from 88% to 99%. The LC50 values determined for 96-hr water-only exposures to SDS ranged from 5.3 mg/l to 9.8 mg/l. All conditions were within acceptable limits. Control charts provided by SAIC showed consistent results in tests of both the positive and negative controls.

Results of the amphipod survival tests for the 100 central Puget Sound sediments are reported in Table 6. Mean percent survival was significantly lower than in controls in seven of the 100 samples (i.e., 7% incidence of "significant" toxicity), and also less than 80% of controls in one of these seven samples (i.e., 1% incidence of "high" toxicity) (station 167, Port Washington Narrows). As a measure of the severity of toxicity, mean survival for the test sediments, expressed as percent of control survival, ranged from 47% (station 167, Port Washington Narrows) to 109% (station 189, Mid Elliott Bay), with results ≥100% for 44 samples.

Sea Urchin Fertilization – Pore Water

Tests were run in three batches. Only 5 samples required adjustments of salinity to 29-31 ppt. Sulfide concentrations were less than the detection limit of 0.01 mg/l in all samples. Dissolved oxygen concentrations in pore water ranged from 6.91 to 8.87 mg/l. Values for pH ranged from 6.77 to 7.57. Total ammonia concentrations in pore waters ranged from 1.27 to 6.49 mg/l and un-ionized ammonia concentrations ranged from 3.8 to 62.8 µg/l. The EC50 values for tests of SDS were 2.32 mg/l, 5.36 mg/l, and 4.03 mg/l, respectively, for the three test series (equivalent results in 1997 were 2.41, 3.23, and 3.51 mg/l in three tests). All conditions were within acceptable limits.

Mean responses for each sample and each porewater concentration are shown in Table 7, along with mean responses normalized to control responses. Four measures of statistical significance are indicated. If percent fertilization was significantly reduced relative to controls (Dunnett's t-test), but fertilization was less than the minimum significant difference (MSD) calculated for *A.*

punctulata, significance is shown as + for alpha <0.05 and shown as ++ for alpha <0.01. If percent fertilization was significantly reduced relative to controls (Dunnett's t-test) and percent fertilization exceeded the minimum significant difference (i.e., <80% of control response), significance is shown as * for alpha <0.05 and ** for alpha <0.01. The MSD value for *A. punctulata* was used, because none is available thus far for *S. purpuratus*.

Results of the urchin fertilization tests for the 100%, 50%, and 25% porewater concentrations from the central Puget Sound sediments indicate that mean percent fertilization was significantly lower than in controls in 16, 14, and 12 of the 100 samples (i.e., 16%, 14%, and 12% incidence of "significant" toxicity) for 100, 50, and 25% pore water, respectively. Percent fertilization success was also both significantly lower and less than 80% of controls in 15, 5, and 9 of the 100 samples (i.e., 15, 5, and 9% incidence of "high" toxicity) for 100, 50, and 25% pore water, respectively. "High" toxicity occurred for all three porewater fractions at stations 115 and 182 (Elliott Bay) and 160 (Sinclair Inlet). Twelve other samples displayed "high" toxicity for 100% porewater, including stations 165 (Sinclair Inlet); 167 and 168 (Port Washington Narrows); 176, 177, 179, 180, 184, and 197 (Elliott Bay); and 199-201 (near Harbor Island). The sample from station 172 (Elliott Bay) also displayed "high" toxicity for both 50 and 25% porewater. Severity of toxicity, based on mean percent fertilization (as % of control), ranged from 2% and 6% in the most toxic samples (station 160, Sinclair Inlet; 115, Elliott Bay; respectively) to 120% (station 185, Elliott Bay), with results $\geq$ 100% for 202 of the 300 tests (all porewater concentrations).

Microbial Bioluminescence (Microtox™) and Human Reporter Gene System (Cytochrome P450) Response - Organic Solvent Extract

The Microtox™ mean EC50 and cytochrome P450 HRGS results are displayed in Table 8. In the Microtox™ tests the mean EC50 value calculated for the Redfish Bay control was 10.57 mg/l. Results for 57 of the Puget Sound stations scattered throughout the study area were statistically significantly reduced relative to the controls and also less than 80% of controls (i.e., a 57% incidence of "high" toxicity). However, none of the Microtox™ tests produced results less than 0.51 mg/l or 0.06 mg/l, the critical lower prediction limit (LPL) values derived for this test during the 1997 survey of northern Puget Sound sediments (Long et al., 1999a). As a measure of the severity of toxicity, EC50 values (as % of control) ranged from 6% (station 168, Port Washington Narrows) to 1697% (station 191, Elliott Bay), with results $\geq$ 100% for 35 of the 100 stations.

The cytochrome P450 HRGS toxicity tests of the 100 sediment samples produced a mean response in the Redfish Bay controls of 0.2 B[a]PEq (µg/g). Results from tests of the central Puget Sound samples ranged from 0.4 (station 116, Admiralty Inlet) to 223 B[a]PEq (µg/g) (station 184, Elliott Bay). Statistical significance of these data compared to the controls was not determined. However, there were 62 and 27 samples in which the responses exceeded, respectively, the 11.1 and 37.1 B[a]PEq (µg/g) upper prediction limit (UPL) critical thresholds derived for the 1997 northern Puget Sound study (Long et al., 1999a). The 27 samples were located primarily in the areas of West Point, Eagle Harbor, Sinclair Inlet, Elliott Bay, and the Duwamish.

As a corollary to and verification of the cytochrome P450 HRGS toxicity tests results, Columbia Analytical Services performed further chemical testing on a select number of the central Puget Sound samples (Jack Anderson, CAS, personal communication). Ten of the samples were selected for cytochrome P450 HRGS analyses at two time periods, exposures of 6 hours and 16 hours. Experimentation with this assay has revealed that the RGS response is optimal at 6 hours of exposure when tests are done with PAHs, whereas the response is optimal at 16 hours when tests are done with dioxins. All ten samples selected for these two time series tests (stations 182, 184, 193, 198-204) were collected in Elliott Bay or the lower Duwamish River. In all the samples except 184, the response was stronger at 6 hours than at 16 hours, indicating the presence of PAHs in the extracts. In most cases, the ratios between the two responses were factors of about five-fold.

Five of the samples (from stations 184, 193, 199, 200, and 204) were selected for chemical analyses for PAHs and PCBs. The correlation between total PAH concentrations in the extracts of five samples and RGS responses was significant ($R^2 = 0.75$). Total PAH concentrations (sums of 27 parent compounds) equaled 240 to 5975 ppb.

In the sample from station 184, the responses at the two time periods were equivalent, suggesting that both chlorinated organics and PAHs were present. However, chemical analyses of the extracts for the five samples indicated that the sums of PCB congeners were very low: 0 to 14 ppb. The highest concentration of PAHs (5975 ppb) was found in sample 184 and the total PCB concentration was 0, contradictory to what was expected. The data suggest that chlorinated organics other than planar PCB congeners may have occurred in sample 184.

Spatial Patterns and Gradients in Toxicity

Spatial patterns (or gradients) in toxicity were illustrated in three sets of figures, including maps for the amphipod and urchin test results (Figures 4-8), Microtox™ results (Figures 9-13), and cytochrome P450 HRGS test results (Figures 14-18). Amphipod and urchin test results are displayed as symbols keyed to the statistical significance of the responses. Stations are shown in which amphipod survival was not significantly different from CLIS controls ($p \geq 0.05$, (i.e.,non-toxic)), was significantly different from controls ($p<0.05$, (i.e., significantly toxic)), or was significantly different from controls ($p<0.05$), and less than 80% of control survival, (i.e., highly toxic). Also, stations are shown on the same figures in which urchin fertilization in 100% pore water was not significantly different from Redfish Bay controls ($p \geq 0.05$, (i.e., non-toxic)), or was significantly different from controls ($p<0.05$) and less than 80% of controls (i.e., highly toxic) in 100% pore water only, in 100% + 50% pore water concentrations, and in 100% + 50% + 25% porewater concentrations. Samples in which significant results were observed in all three porewater concentrations were considered the most toxic.

Microtox™ and cytochrome P450 HRGS data are shown as histograms for each station. Microtox™ results are expressed as the mean EC50 (mg/ml), therefore, as in the report for the 1997 survey, the height of the bar decreases with increasing toxicity. Dark bars indicate nonsignificant results (i.e., not significantly different from Redfish Bay controls ($p \geq 0.05$, (i.e., non-toxic)), while light bars indicate results were significantly different from controls ($p<0.05$) and less than 80% of controls (i.e., toxic response). In the cytochrome P450 HRGS assays, data are expressed as benzo[a]pyrene equivalents (μg/g) of sediment. For these results, high values indicate the presence of toxic chemicals (i.e., the height of the bar increases with increasing toxicity).

Amphipod Survival and Sea Urchin Fertilization

Among the samples collected in Port Townsend, Admiralty Inlet, lower Possession Sound, and the central basin (strata 1-12), there was a general trend of non-toxic conditions, with only three significantly toxic responses in the test for amphipod survival, and no significant responses in the urchin fertilization tests (Figures 4-6). Amphipod survival was significantly reduced in the samples from station 106 (South Port Townsend), station 123 (Central Basin), and station 134 (near Blake Island).

None of the results were statistically significant (i.e., all samples were non-toxic) in either of these two tests for samples from Liberty Bay (stratum 13), Keyport (stratum 14), the Bainbridge basin (strata 15, 16), Rich Passage (stratum 17), and Dyes Inlet (stratum 22) (Figures 5 and 7). Amphipod survival, however, was significantly toxic in one sample from stratum 18 (station 158, Port Orchard) and highly toxic (the only sample in the survey with this result) in one sample from stratum 21 (station 167, Port Washington Narrows). Urchin fertilization also displayed significant toxicity in 100% pore water at stations 165 (Sinclair Inlet), and 167 and 168 (Port Washington Narrows), and was highly toxic in all porewater concentrations in the sample from station 160 (Sinclair Inlet) (Figure 7).

There were only two significantly toxic responses in the test for amphipod survival in Elliott Bay, at stations 181 (shoreline) and 202 (east Harbor Island) (Figure 8). Toxicity in the sea urchin tests was much more apparent among the samples collected in Elliott Bay. Samples from strata 24-26 along the Seattle shoreline and strata 30 and 31 (east and west Harbor Island) displayed varying degrees of toxicity to the sea urchin fertilization tests.

Microbial Bioluminescence (Microtox™)

With a few exceptions, samples from the northern region of the study area (strata 1,2,4, and 5) demonstrated minimal responses (i.e., high bars) in the Microtox™ tests (Figure 9). Four stations, 106 and 107 (south Port Townsend), station 112 (south Admiralty Inlet), and station 118 (Possession Sound) all displayed highly significant levels of toxicity in response to the test for microbial bioluminescence.

Continuing farther south in Puget Sound, samples from strata 6-12 displayed both significant and nonsignificant Microtox™ results (Figures 10 and 12). There was no clear spatial pattern in these results from the central basin area, with the exception of stratum 9 (Eagle Harbor), in which samples from all three stations displayed significant Microtox™ results.

Samples from strata 13-16 and 18-22 in the Bainbridge Basin all displayed significant responses to the Microtox™ tests with the exception of station 165 in Sinclair Inlet (Figures 10 and 11). None of the stations from stratum 17 (Rich Passage) displayed significant responses. The relatively high toxicity levels in samples from stations 148-150 (Figure 10) continued southward to station 151, then decreased steadily southward through stations 153, 152 and 156 (Figure 11). Toxicity then again increased toward and into Sinclair Inlet.

In Elliott Bay, significant results of the Microtox™ tests were seen in stratum 23 (outer Elliott Bay) and at nearby station 190 (mid Elliott Bay); at shoreline stations 176, 177, 115, and 183; at stations 114 and 197 (west Harbor Island) and station 201 (east Harbor Island); and at stations 203-205 (Duwamish River). Five of these stations also displayed toxicity with the sea urchin tests. As stated earlier, none of the Microtox™ test results indicated significant toxicity when compared to the 80 and 90% Lower Prediction Limit (LPL) critical values generated for the 1997 data set (Long, et al., 1999a).

Human Reporter Gene System (Cytochrome P450)

Results of this test are illustrated as histograms for each station (Figures 14-18). High values are indicative of a response to the presence of organic compounds, such as dioxins, furans, and PAHs in the sediment extracts. Data are shown as benzo[a]pyrene equivalents (μg/g). Using the nationwide NOAA database and the 1997 PSAMP/NOAA Northern Puget Sound Sediment Quality study, critical values of >11.1 and >37.1 μg/g benzo(a)pyrene equivalents/g sediment were calculated as the 80% and 90% upper prediction limit critical values for this toxicity parameter (Long, et al., 1999a).

Minimal responses were observed in all samples from strata 1,2,4, and 5 in the northern region of the study area (Figure 14), and strata 6-7 (Figure 15). With the exception of the sample taken at station 141 (East Passage), stations in stratum 9 (Eagle Harbor); strata 8, 11, and 12 (Central Basin); and station 135 in stratum 10 all displayed a response above the > 80% upper prediction limit critical value. Results from three of these 14 stations also exceeded the 90% upper prediction limit critical values (Figures 15, 17).

Slightly elevated responses (between the 80 and 90% upper prediction limits) were apparent in samples from Liberty Bay (stations 143, 144, 146) and stations 148, 151, and 153 (Figures 15-16). The cytochrome P450 HRGS responses in samples from stratum 16 diminished southward into stratum 17 (no elevated results) and then increased again in strata 18-22 (Dyes and Sinclair Inlets, and Port Washington Narrows) (Figure 16). Samples from 11 of the 15 stations in these strata displayed cytochrome P450 HRGS responses above either the 80 or 90% upper prediction limits.

Minimal cytochrome P450 HRGS responses were displayed in outer Elliott Bay (strata 23 and 24) (Figure 18). In contrast, samples from inner Elliott Bay and the Duwamish (strata 25-32) gave the highest P-450 responses among all study samples. Cytochrome P450 HRGS assay results exceeded either the 80 or 90% criteria values, with the exception of the sample from station 190.

Summary

Several spatial patterns identified with results of all the tests were apparent in this survey. First, samples from the Admiralty Inlet/Port Townsend area and much of the central main basin were among the least toxic. Second, many of the samples from the Liberty Bay and Bainbridge basin area were toxic in the Microtox™ and cytochrome P450 HRGS assays. The degree of toxicity decreased steadily southward down the Bainbridge basin to Rich Passage, where the sediments were among the least toxic. Third, samples from two stations (167 and 168) located in a small inlet off Port Washington Narrows were among the most toxic in two or more tests. Fourth, several samples from stations scattered within Sinclair Inlet indicated moderately toxic conditions; toxicity diminished steadily eastward into Rich Passage. Finally, and perhaps, foremost, were the highly toxic responses in the sea urchin, Microtox™, and cytochrome P450 HRGS tests observed in the strata of inner Elliott Bay and the lower Duwamish River. Toxicity in these tests generally decreased considerably westward into the outer and deeper regions of the bay.

Spatial Extent of Toxicity

The spatial extent of toxicity was estimated for each of the four tests performed in central Puget Sound with the same methods used in the 1997 northern Puget Sound study (Long et al., 1999a), and reported in Table 9. The critical values used in 1997 were also applied to the 1998 data. The 33 strata were estimated to cover a total of about 732 km^2 in the central basin and adjoining bays.

In the amphipod survival tests, control-normalized survival was below 80% in only one sample (station 167 Port Washington Narrows), which represented about 1.0 km^2, or about 0.1% of the total area. In the sea urchin fertilization tests of 100%, 50%, and 25% pore waters, the spatial extent of toxicity (average fertilization success <80% of controls; i.e., highly toxic) was 5.1, 1.5, and 4.2 km^2, respectively, or 0.7%, 0.2%, and 0.6% of the total area. Usually, in these tests the percentages of samples in which toxic responses are observed decrease steadily as the pore waters are diluted. However, in this case the incidence of toxicity and, therefore, the spatial extent of toxicity, was higher in tests of 25% pore waters than in the tests of 50% pore waters. There is no apparent explanation for this discrepancy from past performance.

The spatial extent of toxicity relative to controls in the Microtox™ tests was 349 km^2, representing about 48% of the total area. However, there were no samples in which mean EC50's were less than 0.51 mg/L or 0.06 mg/L, the statistically-derived 80% and 90% lower prediction limits of the existing Microtox™ database. In the cytochrome P450 HRGS assays, samples in which the responses exceeded 11.1 µg/g and 37.1 µg/g (the 80% and 90% upper prediction limits of the existing database) represented about 237 km^2 and 24 km^2, respectively. These areas were equivalent to 32% and 3%, respectively, of the total survey area.

Concordance among Toxicity Tests

Non-parametric Spearman-rank correlations were determined for combinations of the four different toxicity tests to determine the degree to which the results co-varied and, therefore, showed the same patterns. It is critical with these correlation analyses to identify whether the coefficients are positive or negative. Amphipod survival, urchin fertilization success and microbial bioluminescence improve as sediment quality improves. However, cytochrome P450 HRGS responses increase as sediment quality deteriorates. Therefore, in the former three tests, positive correlation coefficients suggest the tests co-varied with each other. In contrast, co-variance of the other tests with results of the cytochrome P450 HRGS assays would be indicated with negative signs.

The data in Table 10 indicate that the majority of the correlations between toxicity tests were not significant, indicating poor concordance among tests. However, cytochrome P450 HRGS responses increased as percent urchin fertilization decreased and this relationship was highly significant ($p \leq 0.0001$). In both of these tests, samples from many of the stations in the northern reaches of the study area and the central basin of the Sound were least toxic, whereas many of the samples collected around the perimeter of Elliott Bay and a few in Sinclair Inlet were highly toxic.

Chemical Analyses

Grain Size

The grain size data are reported in Appendix D, Table 1, and frequency distributions of the four particle size classes, % gravel, % sand, % silt, and % clay, are depicted for all stations in Appendix D, Figure 1. From these data, sediment from the 100 stations were characterized into four groups (sand, silty sand, mixed sediments, and silt-clay) based on their relative proportion of % sand to % fines (silt + clay)(Table 11). Among the 100 samples from central Puget Sound, 30 were composed primarily of sand, 15 of silty sand, 23 had mixed sediments, and 32 were made up primarily of silt-clay particles.

Total Organic Carbon (TOC), Temperature, and Salinity

Total organic carbon (TOC) and temperature measurements taken from the sediment samples, and salinity measurements collected from water in the grab, are displayed in Appendix D, Table 2. Values for TOC ranged between 0.1 and 4.2%, with a mean of 1.4%. Eight of the 100 stations had TOC values lower than 0.2% which should be considered when comparing TOC normalized data from these stations to Washington State sediment criteria (Michelsen, 1992). Temperature ranged between 11.0 and 14.5 °C, with a mean of 12.4 °C. Salinity values ranged between 25-34 ppt, with a mean of 30.5 ppt.

Metals and Organics

Appendix D, Table 3 summarizes metal and organic compound data, including mean, median, minimum, maximum, range, total number of values, number of undetected values, and the number of missing values. Values for tin (partial digestion) and monobutyl tin were not obtained due to contamination of samples during the digestion and analysis processes at the lab. The majority of compounds quantified were reported as undetected at method quantitation limits in one or more samples. These compounds included 6 of 24 metals (strong acid digestion), 23 of 23 metals (hydrofluoric acid digestion method), 1 of 1 miscellaneous elements, 2 of 2 organotins, 23 of 23 organic compounds quantified through BNA analyses, 33 of 46 low and high molecular weight polynuclear aromatic hydrocarbons, and all 56 chlorinated pesticides and polychlorinated biphenyl (PCB) compounds.

Spatial Patterns in Chemical Contamination

The spatial (geographic) patterns in chemical contamination were determined by identifying on maps the locations of sampling stations in which numerical sediment quality guidelines (ERM, SQS, and CSL values) were exceeded (Figures 19-23). Tables 12 and 13 provide detail regarding the specific chemical compounds that exceeded these guideline values at each station. The number of compounds exceeding the ERL values and the mean ERM quotient calculated for each station, are also provided in Tables 12 and 13, and discussed below.

Spatial patterns in chemical contamination in strata 1,2,4, and 5 near Port Townsend, southern Admiralty Inlet, and in Possession Sound, are displayed in Figure 19 and summarized in Table 12. None of the ERM values were exceeded in these 12 sediment samples. The ERM quotients for all samples except those from stations 107 and 118 were less than 0.1, suggesting that very little contamination occurred in this area. For samples 107 and 118, three chemicals exceeded the ERL values, and mean ERM quotients were 0.24 and 0.13, respectively, suggesting a slight degree of contamination. One chemical, 4-methylphenol, exceeded state SQS and CSL values at six stations within strata 1,2,4, and 5. Five of these samples were collected in Port Townsend (stations 106-109, 111) and the other near Mukilteo (station 118) in Possession Sound.

None of the chemical concentrations in samples from strata 6-8 in the central basin and Port Madison, and in strata 13-15 (Liberty Bay/Keyport/Bainbridge Island) exceeded ERM values (Figure 20, Table 12). Mean ERM quotients in these samples were low (0.04 to 0.26). Samples with chemical concentrations exceeding ERL values included those from stations 128 (16 compounds); 142-144, 146 (4 each); 148 (3); 129 (2); and 122, 123(1 each). As in strata 1,2,4, and 5, the SQS and CSL values for 4-methylphenol were exceeded in samples 113, 122, 123, and 148, again suggesting these samples were only slightly contaminated.

In the samples collected in the southern reaches of the central basin and Eagle Harbor, all chemical concentrations were below the ERM values (Figure 21, Table 12). However, in samples 130 and 131 from Eagle Harbor, mean ERM quotients were 0.33 and 0.36 and 17 and 19 ERLs were exceeded, respectively, in these samples, suggesting a slight degree of contamination. The CSL concentration for 4-methylphenol was again exceeded in the sample from station 140. No other samples from strata 9-12 had chemical concentrations exceeding Washington State sediment standards.

Figure 22 and Table 12 summarize spatial patterns for chemical contamination in the sediments collected near Bainbridge Island, Port Orchard, and Bremerton (strata 16-22). Contaminant levels in the samples collected from strata 16 through 18, 21, and station 169 (Dyes Inlet) were all measured below ERM values, with low mean ERM quotients (0.04 - 0.19). The ERL values were exceeded at stations 151 and 153 (SW Bainbridge Island), and 168 (Port Washington Narrows), while the CSL values for benzyl alcohol was exceeded only at station 151.

Samples from stations 170 and 171 in Dyes Inlet also displayed no contaminant levels above ERM values, with the exception of nickel at station 170. Long et al. (1995), however, suggested that there was a limited degree of reliability in the ERM value for nickel, and that nickel does not play a major role in causing toxicity. The mean ERM quotient values were higher, 0.25 and 0.26, respectively, and each station had 10 compounds exceeding ERL values. Again, the SQS value for benzyl alcohol was exceeded at both stations, while both SQS and CSL values for mercury were exceeded at station 171. With the exception of station 161, all six samples collected from Sinclair Inlet exceeded the ERM value for mercury. Mean ERM quotients at these stations were high, ranging from 0.27 to 0.55, and ERL values were exceeded for 7 to 11 compounds in each sample. All six samples exceeded the SQS and CSL values for mercury.

Spatial patterns in chemical contamination in the sediments collected in Elliott Bay and the Duwamish River are summarized in Figure 23 and Table 13. The degree of chemical contamination increased steadily and considerably from the outer to the inner reaches of the bay. Sediment samples collected from the outer bay (strata 23, 24, and 28) had no chemical concentrations exceeding ERM values, mean ERM quotients ranging between 0.06 and 0.45, and ERL values were exceeded for 0 to 16 compounds. Sediments from stations 174, 176, and 190 did, however, have concentrations of butylbenzylphthalate (stations 174, 176), di-n-butylphthalate (station 190), and mercury, benzo(g,h,i)perylene, and phenanthrene (station 176) above the SQS levels.

Samples collected along the Seattle shoreline and inner bay (strata 25-27,29) and in the lower Duwamish River (strata 30-32) were the most contaminated among the 100 tested in central Puget Sound. In the samples from these seven strata, many chemical compounds (up to 25 per station) had concentrations exceeding ERL levels, and mean ERM quotients ranged from 0.37 to 3.93. Notable among these 25 samples were those from 11 stations (i.e., 181, 182, 184, 188, 194, 198, 114, 200, 201, 202, and 205) in which chemical concentrations exceeded 20 to 25 ERL values, and mean ERM quotients exceeded 1.0 (1.05-3.93).

Within these seven strata, a variety of compounds (up to 10 per station) had concentrations exceeding ERM, SQS, and CSL values. Some unique patterns were discerned with regard to the chemical compounds that exceeded national guidelines and state criteria. Mercury values exceeded only the state criteria, and only at some of the shoreline and mid-Elliott Bay stations, while other metals were detected above state criteria (arsenic) and national guidelines (arsenic and zinc) near West Harbor Island only (station 197). The majority of the samples exceeding HPAH national guidelines and state criteria were collected from shoreline and mid-Elliott Bay stations. With one exception (station 198), total LPAH values exceeded only national guidelines. However, one LPAH compound (phenanthrene) exceeded both state criteria and national guidelines at some shoreline and mid-Elliott Bay stations, while four other LPAH compounds (2-methylnaphthalene, acenaphthene, fluorene, and naphthalene) exceeded both sets of values at the three West Harbor Island stations (stratum 30). Total PCBs exceeded ERM values only. They did not exceed SQS and CSL values. Phenol concentrations (primarily 4-methylphenol), however, exceeded only state criteria, and were found primarily in the Harbor Island and Duwamish River samples. The phthalate esters bis(2-ethylhexyl)phthalate and butylbenzylphthalate were found only in the East Harbor Island and Duwamish River samples. Four other compounds which exceeded state criteria only included dibenzofuran (station 183 and 198), benzyl alcohol (station 188), 1,4-dichlorobenzene (station 200), and pentachlorophenol (station 205).

Summary

The majority of compounds for which chemical analyses were conducted on the 100 sediment samples from central Puget Sound were measured at levels below state criteria and national guidelines (i.e., ERM, SQS, and CSL values). Eleven stations, located in Port Townsend, Possession Sound, the central basin, the Bainbridge basin, and East Passage, all exceeded Washington State SQS and CSL levels for the compound 4-methylphenol. Three stations, one west of Bainbridge Island and two in Dyes Inlet, exceeded state criteria for benzyl alcohol. One of these, in Dyes Inlet, also exceeded state criteria for mercury. The six stations in Sinclair Inlet also exceeded SQS and CSL levels for mercury, while five of the six also exceeded the ERM level for mercury. Sediment samples collected at stations located in Elliott Bay and the Duwamish River clearly showed an increase in the number of compounds exceeding state criteria and national guidelines from outer to inner Elliott Bay, and into the Duwamish River. The suites of compounds exceeding criteria differed between the shoreline/mid-Elliott Bay samples and those collected around Harbor Island and further up the Duwamish River, reflecting differing sources of contamination. In general, spatial patterns of chemical contamination indicated that the highest chemical concentrations invariably occurred in samples collected in urban/industrialized embayments, including Elliott Bay, Sinclair Inlet, Dyes Inlet, and Port Townsend. Often, these samples contained chemicals at concentrations previously observed to be associated with acute toxicity and other biological effects. Concentrations generally decreased steadily away from these embayments and were lowest in Admiralty Inlet, Possession Sound, Rich Passage, Bainbridge Basin, and most of the central basin.

Spatial Extent of Chemical Contamination

Table 14 summarizes the numbers of samples in which ERM, SQS, and CSL concentrations were exceeded and an estimate of the spatial extent of chemical contamination (expressed as the percentage of the total survey area these samples represent) for all compounds with chemical guidelines. For some compounds, the data were qualified as "undetected" at method quantitation limits that exceeded the chemical guideline values. In these cases, the spatial extent of chemical contamination was recalculated after omitting the data that were so qualified (shown as ">QL only" on Table 14).

Among the trace metals, the concentration of arsenic exceeded ERM, SQS, and CSL values at station 197, West Harbor Island (0.04% of the study area). The level of zinc also exceeded the ERM value at this station. Mercury exceeded all three sets of criteria in sediment collected from 9 to 14 stations in Sinclair and Dyes Inlets, and in Elliott Bay, representing 1.1 (ERM), 2.0 (SQS), and 1.9% (CSL) of the study area. The ERM value for nickel was exceeded in four samples. As stated earlier, however, Long et al. (1995) suggested that there was a limited degree of reliability in this value. For all trace metals (excluding nickel), there are a total of 10 (ERM), 15 (SQS), and 13 (CSL) samples exceeding guidelines or criteria levels, encompassing a total of 2.5, 2.0, and 1.9%, respectively, of the total study area.

Many of the low and high molecular weight polynuclear aromatic hydrocarbons (LPAH and HPAH) were found at concentrations that exceeded the guidelines in samples from Elliott Bay, West Harbor Island, and the Duwamish River. As noted earlier, different suites of PAHs exceeded state criteria and national guidelines at different locations, with the majority of the LPAH compounds detected above these values in the West Harbor Island samples, and the majority of the HPAH compounds found in the Elliott Bay and Duwamish River samples. There were 6, 15, and 3 samples in which the concentration of at least one PAH compound exceeded the ERM, SQS, or CSL values, respectively, representing areas equivalent to 0.4%, 0.7%, and 0.07% of the total survey area.

The concentrations of phenols were low in the central Puget Sound stations, with the exception of 4-methylphenol, which was elevated above the SQS and CSL values in 22 samples scattered throughout the study area (23% of the total area). The concentration of the compound 2,4-dimethylphenol was elevated above SQS and CSL levels at station 188 in Elliott Bay (0.14% of the study area), while the concentration of pentachlorophenol was elevated above the SQS value at station 205 in the Duwamish River (0.03% of the study area).

Phthalate ester concentrations, including bis(2-ethylhexyl)phthalate, butylbenzlphthalate, and di-n-butylphthalate, were detected above state criteria levels only in the stations from Elliott Bay, East Harbor Island, and the Duwamish River. There were a total of 7 samples with phthalate ester concentrations exceeding SQS criteria (0.76 % of study area), and 1 sample exceeding the CSL criteria (0.03% of the study area).

The concentrations of chlorinated pesticides for which national guidelines exist were found to be below ERM levels for both 4,4'-DDE and total DDT. Total PCB congeners (>QL data) exceeded the ERM value in 12 samples, located in Elliott Bay, East and West Harbor Island, and the Duwamish River, and covered 0.55% of the total study area. In contrast, total PCB Aroclor concentrations exceeded the SQS value in 36 samples and the CSL in one sample, but all of these concentrations were measured at or below the method quantitation limits reported by MEL, and these limits exceeded the guideline values.

Five of the nine compounds in the remaining suite of miscellaneous compounds were not found above guideline levels in any samples, or were measured at or below method quantitation limits that exceeded the guideline values. The compound 1,4-dichlorobenzene was measured above its SQS value at station 200 (0.02% of the study area), collected east of Harbor Island. Benzyl alcohol was measured above its SQS value at stations collected near Bainbridge Island, in Dyes Inlet, and Elliott Bay (1.7% of the study area), and above its CSL concentration at the Bainbridge Island station (0.5% of the study area). Dibenzofuran was measured above its SQS value at one station in Elliott Bay and three stations collected west of Harbor Island (0.13% of the study area), and above its CSL value at one of the West Harbor Island stations (0.04% of the study area). High concentrations of benzoic acid were found almost ubiquitously throughout the central Puget Sound study area, exceeding the SQS and CSL concentrations in 89 samples. These samples represented about 81% of the total study area.

When all the chemical concentrations for which ERM values were derived (excluding nickel) were compared to their respective guidelines, 21 samples had at least one reliable chemical concentration greater than an ERM value. These 21 samples represented about 1.6% of the total survey area. In contrast, there were 95 and 94 samples in which at least one SQS or CSL value (respectively) was exceeded, representing about 99% of the survey area. Excluding the data for both nickel and benzoic acid, 44 samples had at least one chemical concentration greater than an SQS value (25.2% of the area) and 36 samples had at least one concentration greater than a CSL value (21.1% of the area).

Summary

The spatial extent of chemical contamination, expressed as the percent of the total study area, was determined for the 54 compounds for which chemical guidelines or criteria exist. Twenty of these compounds were measured at levels that were below the SQS and CSL guidelines, and were at or below the ERM guidelines, for all 100 stations sampled in central Puget Sound. Thirty-four (33 excluding nickel) were measured at or above at least one of the guideline values in at least one station. For 29 of these 34 compounds (including arsenic, zinc, LPAHs, HPAHs, phthalate esters, PCB congeners, 1,4-dichlorobenzene, and dibenzofuran), the spatial extent of chemical contamination represented less than 1% of the total study area and was confined to the stations sampled in the urban/industrialized areas of Elliott Bay and the Duwamish River. Four of the five remaining compounds were measured above guideline levels in greater than 1% of the study area, including mercury (1.11-1.98%, Dyes and Sinclair Inlets, Elliott Bay), nickel (1.31%, Liberty Bay, Bainbridge Island, Dyes Inlet), 4-methylphenol (23%, Port Townsend, Possession Sound, Central Basin, East Passage, Bainbridge Island, Elliott Bay, and the Duwamish River), and benzyl alcohol (0.47-1.67%, Bainbridge Island, Elliott Bay, and the Duwamish River). Again, the majority of these compounds exceeding criteria values were located in samples collected from urban/industrialized locations. High concentrations of benzoic acid were found in about 81%, located around the central Puget Sound study area.

Relationships between Measures of Toxicity and Chemical Concentrations

The associations between the results of the toxicity tests and the concentrations of potentially toxic substances in the samples were determined in several steps, beginning with simple, non-parametric Spearman-rank correlation analyses. This step provided a quantitative method to identify which chemicals or chemical groups, if any, showed the strongest statistical relationships with the different measures of toxicity.

Toxicity vs. Classes of Chemical Compounds

Spearman-rank correlation coefficients (rho) and probability (p) values for the four toxicity tests versus the concentrations of four different groups of chemicals, normalized to the respective ERM, SQS, and CSL values, are listed in Table 15. None of the correlations were significant for tests of amphipod survival. In this study, significant statistical correlations between amphipod survival and chemical concentrations would not be expected because percent survival was very similar among most samples. Results of the Microtox tests were correlated (Rho = 0.37, $p \leq 0.01$) only with summed concentrations of low molecular weight PAHs normalized to the SQS and CSL guidelines.

In contrast, percent urchin fertilization and cytochrome P450 HRGS induction were highly correlated with many of the chemical groups when normalized to all three sets of guidelines. Percent urchin fertilization was significantly correlated with all but the trace metals groups at probability levels ≤ 0.0001. Correlations with the concentrations of PAHs were consistent and highly significant. Correlations with trace metals were weaker. In the cytochrome P450 HRGS assays, enzyme induction was very highly correlated with trace metals, chlorinated organics, PAH concentrations, and mean ERM quotients for all 25 substances.

Among all the possible toxicity/chemistry correlations, the strongest statistical association was between the cytochrome P450 HRGS responses and the concentrations of 13 PAHs normalized to their respective ERM values (Rho = 0.928, $p \leq 0.0001$) as shown in Table 15. These data are shown in a scatterplot (Figure 24) to illustrate the relationship. In general, cytochrome P450 HRGS responses increased as PAH concentrations increased. Induction was greatest in the sample from station 184 which also had the highest concentrations of PAHs; thereby, contributing to the highly significant statistical correlation.

Toxicity vs. Individual Chemicals

Correlations between measures of toxicity and concentrations of individual trace metals determined with partial digestions are summarized in Table 16. Most metal concentrations were highly significantly correlated ($p \leq 0.0001$) with cytochrome P450 HRGS induction, while a few were correlated to a lesser extent with percent urchin fertilization and microbial bioluminescence. None were correlated with amphipod survival. Urchin fertilization was most significantly correlated with lead, suggesting that fertilization success diminished as the lead concentration increased. However, the scatter plot of this data (Figures 25), indicated that there was not a clear pattern of decreasing percent fertilization corresponding with increasing lead concentrations. Furthermore, none of the samples had lead concentrations above the state standards. Better correspondence was seen in the scatter plot of microbial bioluminescence EC50s and cadmium concentration, with EC50 values decreased to their lowest level at cadmium concentrations greater than 0.5ppm (Figure 26).

Because the microbial bioluminescence and cytochrome P450 HRGS tests are performed with organic solvent extracts, trace metals are not expected to contribute significantly to the biological responses in these tests. The correlations between results of these two tests and concentrations of trace metals (Table 16) that appeared to be highly significant may reflect the co-variance in concentrations of metals and the organic toxicants that were eluted with the solvents.

Correlations between measures of toxicity and concentrations of individual trace metals determined with total digestions are summarized in Table 17. Again, no significant correlations are seen with Amphipod survival. Similar to the results observed for the partial digestions, percent fertilization and microbial bioluminescence were correlated with the concentrations of just a few metals determined with total digestions, while cytochrome P450 HRGS induction was highly correlated with most of the metals. The urchin tests were performed with pore waters, instead of organic solvent extracts. Also, these animals are known to be sensitive to trace metals. Therefore, if the presence of trace metals in the samples contributed to toxicity observed in these tests, the correlation coefficients between urchin fertilization and metals concentrations might be expected to increase with the data for total digestions relative to those for partial digestions, because the concentrations would be higher in the total digestions. However, the correlations in Tables 16 and 17 showed only slight differences, and the examination of the scatter plot of the relationship between urchin fertilization results and tin concentrations showed that the highly significant negative correlation was driven by the results from just a few samples (Figure 27).

Both percent urchin fertilization and cytochrome P450 HRGS induction were significantly correlated with the concentrations of most individual low molecular weight PAHs (LPAH) and the sums of these compounds (Table 18). The correlations with cytochrome P450 HRGS induction were very similar among the LPAHs, suggesting these compounds co-varied with each other to a large degree. The highest correlation of any toxicity test with any chemical parameter was between the cytochrome P450 HRGS and the HPAHs (rho = 0.718-0.946, $p \leq 0.0001$)(Table 19). The cytochrome P450 HRGS assay is known to be sensitive to, and was designed to detect, the presence of HPAH. Correlation coefficients, while also highly significant, were lower with urchin fertilization (rho = -0.413- -0.623, $p \leq 0.0001$). Microbial bioluminescence generally was not highly correlated with the concentrations of these compounds, and amphipod survival, as with the metals, was not correlated with either LPAH or HPAH results (Table 19).

The concentrations of the sums of 13 dry-weight normalized PAHs (national guidelines; Long et al., 1995) and 15 TOC-normalized concentrations (Washington State Sediment Management Standards; Chapter173-204 WAC, 1995) were highly correlated with percent urchin fertilization and cytochrome P450 HRGS results. Fertilization success was highest among samples with the lowest concentrations (Figures 28, 29). However, fertilization success did not decrease steadily with increasing concentrations and the only sample in which the total PAH concentration exceeded the ERM was not toxic; thereby suggesting that fertilization success was not controlled by these substances.

In contrast to the data from the urchin tests, enzyme induction in the cytochrome P450 HRGS tests was consistently lowest in samples with lowest total PAH concentrations, increased steadily as concentrations increased above the ERL levels, and generally was highest in samples in which the ERM was exceeded (Figure 30). Normalization of the PAH concentrations to TOC content decreased the correlation (Figure 31) due to increased variability in the association.

Results of the four toxicity tests were also examined for relationship with the concentrations of various butyltins, phenols, and miscellaneous organic compounds (Table 20). No significant correlations were seen between amphipod survival and these compounds. Fertilization success was highly significantly correlated with the two butyltin compounds, and began to diminish as the concentrations of dibutyltin exceeded 60 ppb and as tributyltin concentrations exceeded 200 ppb (Figures 32, 33). Percent fertilization, however, was very high in the sample from station 187 in which the tributyltin concentration was highest. Fertilization success was also significantly correlated with dibenzofuran. In the microbial bioluminescence tests, bioluminescence activity was highly correlated to, and decreased steadily with, increasing concentrations of benzoic acid (Figure 34). Similar to results in the urchin tests, cytochrome P450 HRGS induction showed a strong degree of correspondence with concentrations of both dibuyltin and tributyltin, and dibenzofuran. Cytochrome P450 HRGS induction seemed to increase when dibutyltin concentrations exceeded about 80 ppb, and tributyltin and dibenzofuran concentrations exceeded about 100 ppb (Figures 35-37).

Cytochrome P450 HRGS induction was significantly correlated with the concentrations of 4-4' DDE and total DDT. Both percent urchin fertilization and cytochrome P450 HRGS induction were significantly correlated (cytochrome P450 HRGS to a greater degree) with the concentrations of individual PCB compounds, and the sums of these concentrations (Table 21).

Isomers of DDT and most PCB congeners are not known to induce the cytochrome P450 HRGS enzyme response, therefore, it is likely that these compounds co-varied with the PAHs and other organic substances that more likely induced the response.

Summary

The toxicity bioassays performed for urchin fertilization, microbial bioluminescence, and cytochrome P450 HRGS enzyme induction indicated correspondence with complex mixtures of potentially toxic chemicals in the sediments. Often, the results of the urchin and cytochrome P450 HRGS tests showed the strongest correlations with chemical concentrations. As expected, given the nature of the tests, results of the cytochrome P450 HRGS assay were highly correlated with concentrations of high molecular weight PAHs and other organic compounds known to induce this enzymatic response. In some cases, samples that were highly toxic in the urchin or cytochrome P450 HRGS tests had chemical concentrations that exceeded numerical, effects-based, sediment quality guidelines or the state criteria, further suggesting that these chemicals could have caused or contributed to the observed biological response. However, there was significant variability in some of the apparent correlations, including samples in which chemical concentrations were elevated and no toxicity was observed. Therefore, it is most likely that the chemical mixtures causing toxicity differed among the different toxicity tests and among the regions of the survey area. These chemical mixtures may have included substances not targeted in the chemical analyses.

Benthic Community Analyses

Community Composition and Benthic Indices

A total of 700 benthic infauna taxa were identified in the 100 samples collected in central Puget Sound (Appendix E). Of the 700 taxa identified, 517 (74%) were identified to the species level. Among the 517 species identified, 243 (47%) were polychaete species, 147 (28%) were arthropods, 78 (15%) were molluscs, and 49 (10%) were miscellaneous taxa (i.e., Cnidaria, Platyhelminthes, Nemertina, Sipuncula, Phoronidae, Enteropneusta, and Ascidiacea) and echinoderms. Several of the species encountered in this survey may be new to science.

As described in the Methods section, five benthic infaunal indices were calculated to aid in the examination of the community structure at each station. These indices included total abundance, major taxa abundance (calculated for Annelida, Arthropoda, Mollusca, Echinodermata, and miscellaneous taxa), taxa richness, Pielou's evenness (J'), and Swartz's Dominance Index (SDI), and were calculated based on the abundance data collected for the 700 taxa found (Tables 22 and 23). Total abundance is displayed in both tables to facilitate comparisons among indices. All data were based on analysis of a single sample collected at each station.

Total Abundance

Total abundance (number of individuals per 0.1 m^2) of benthic invertebrates at each station (Tables 22 and 23) ranged from 3,764 organisms at station 203 (Duwamish) to 110 organisms at station 118 (Possession Sound). In approximately half (15 of 32) of the strata, total abundance was relatively consistent among the samples collected within each stratum. However, among samples within several strata there were differences in total abundance up to an order of magnitude of ten. These strata included South Admiralty Inlet (stratum 4), Central Basin (stratum 6), Sinclair Inlet (stratum 19), Elliott Bay (strata 24, 25, 28, and 29), and the Duwamish (stratum 32). In most of these cases, high numbers of a single polychaete species (*Aphelochaeta* species N1) accounted for the inflated abundance in one of the samples within the stratum.

Major Taxa Abundance

Total abundance and percent total abundance of five major taxonomic groups (Annelida, Arthropoda, Echinodermata, Mollusca, and miscellaneous taxa) are shown in Table 22. Results also are compared among stations in stacked histograms (Appendix F).

The total abundance of annelids ranged from 2,970 animals (station 203, Duwamish) to 30 animals (station 123, Central Basin). Annelid abundance calculated as the percentage of total abundance ranged from 94% (station 115, Shoreline Elliot Bay) to 6% (station 177, Shoreline Elliot Bay). In 36% of the 100 stations sampled, fifty percent or more of the total benthic infaunal animals were annelids. In 67% of the samples, one-third or more of the animals in the benthic communities were annelids.

Total abundance of arthropods ranged from 1,349 animals (station 112, South Admiralty Inlet) to 3 (station 160, Sinclair Inlet). Percent total abundance of arthropods ranged from 58% in South Admiralty Inlet (station 112) to 1% in Elliott Bay (station 115), the Duwamish (station 205), and East Harbor Island (station 202). Arthropods made up 50% or more of the total benthic infaunal assemblage in only 5% of the 100 stations sampled (stations 134 and 121, Central Basin; 171, Dyes Inlet; 190, Mid Elliott Bay; and 112, South Admiralty Inlet), and 33% of the total abundance in only 20% of the samples.

Total abundance of molluscs ranged from 822 animals at station 177 (Shoreline Elliott Bay) to 4 at station 142 (Liberty Bay). Percent total abundance of molluscs ranged from 75% (station 155, Rich Passage) to 1% at station 142 (Liberty Bay). Molluscs were numerically dominant (i.e., made up 50% or more of the total assemblage) in 13% of the samples, including those from stations in Port Townsend (110), Port Orchard (157), west of Bainbridge Island (149, 152), Shoreline (177) and Mid Elliott Bay (186-188, 193-194, 196), and Rich Passage (154-155). Thirty-eight percent of the samples had a 33% or greater portion of their infaunal assemblage composed of molluscs.

Total abundance of echinoderms ranged from 421 at station 108 (South Port Townsend) to 0 at 20 stations, sampled primarily in the central basin (strata 6, 8, and 11) and Elliott Bay (strata 23, 25, and 28-32). These stations also represented the highest and lowest percent total echinoderm abundance, ranging from 60% (South Port Townsend, station 108) to 0% at the suite of 20 stations in the central basin and Elliott Bay. There were no echinoderms in 20% of the samples, and five or fewer individuals in 60% of the samples. Echinoderms made up greater than 50% of the total benthic infaunal assemblage in only 2 of the 100 stations sampled, stations 146 (Keyport) and 108 (South Port Townsend), and 33% of the total abundance in only 5 of the stations (stations 146, 108, and stations 148, 150, and 151 (northwest of Bainbridge Island).

Total abundance of miscellaneous taxa (i.e., Cnidaria, Platyhelminthes, Nemertina, Sipuncula, Phoronidae, Enteropneusta, and Ascidiacea) ranged from 59 organisms at station 112 (South Admiralty Inlet)) to none at five stations (station 120, Possession Sound; station 143, Liberty Bay; station 146, Keyport; and stations 115 and 196, Elliott Bay. Percent total abundance of miscellaneous taxa ranged from 6% to 0%.

Taxa Richness

Taxa richness (total number of recognizable species in each sample, Table 23) ranged from 176 taxa in South Admiralty Inlet (station 112) to 21 taxa in Sinclair Inlet (station 160). Stations with highest taxa richness (>100 taxa) included stations at Port Townsend (stations 109 and 111), Rich Passage (station 156), Port Orchard (station 158), and Elliott Bay (stations 174, 175, 183, and 189). Stations with lowest taxa richness (<30 taxa) included Liberty Bay (stations 142-144), Keyport (station 146), and Sinclair Inlet (station 160).

Evenness

Pielou's index of evenness (Table 23) ranged from 0.910 (high homogeneity or good evenness) in Possession Sound (station 118) to 0.255 (low homogeneity or poor evenness) in Elliott Bay (station 115). Relatively high evenness values (J'>0.800) were calculated from samples collected in Port Townsend (stations 106, 107, and 109); South Admiralty Inlet (station 117); Possession Sound (station 118), the central basin (stations 122, 135-138), and East Passage (stations 140-141); the waterways west of Bainbridge Island (stations 145, 153, 156, 159); and outer and shoreline Elliott Bay (stations 172, 174, 175, 181). Low evenness values (J'<0.400) occurred in samples from inner Elliott Bay (station115); the Duwamish (114, 201, and 204), and Sinclair and Dyes Inlets (161 and 168).

Swartz's Dominance Index (SDI)

Swartz's Dominance Index (SDI) values (Table 23) ranged from 48 taxa making up 75% of the total abundance in outer Elliott Bay (station 175) to 1 dominant taxon at inner Elliott Bay (stations 115) and Dyes Inlet (station 168). Approximately one-half of the stations sampled (52%) had a SDI value of 10 or less. Some of these stations were distributed throughout the sampling area, but most were concentrated in Liberty Bay, Sinclair Inlet, Dyes Inlet, inner Elliott Bay, and the Duwamish. Nineteen percent of the samples had SDI values of 20 or greater, and were collected in Port Townsend Bay (stations 106, 107, 109, 111); the central basin and East Passage (stations 135, 141); Rich Passage and Port Orchard (station 154, 156, 158, 159); Dyes Inlet (station 166), and portions of outer and inner Elliott Bay (stations 174-176, 178, 181-184). SDI values generally followed the same pattern as Pielou's Evenness values, with low evenness values co-occurring with low SDI values.

Summary

Generally, the samples collected in central Puget Sound exhibited moderately high total abundance accompanied by relatively high taxa richness, evenness, and SDI. However, stations with the highest total abundance often had low taxa richness, evenness, and SDI values. In most cases, this was due to high numbers of the cirratulid polychaete, *Aphelochaeta* species N1. These samples were collected primarily in Sinclair and Dyes Inlets, inner Elliott Bay, and the Duwamish.

Relationships between Benthic Infaunal Indices and Sediment Characteristics, Toxicity, and Chemical Concentrations

The statistical relationships between indices of benthic community structure and selected sediment characteristics were calculated using Spearman rank correlations. These correlations were used to determine if any of the measures of benthic community structure co-varied with any of the sediment characteristics quantified in this study. Measures of naturally occurring sediment variables such as grain size and total organic carbon (Table 24), toxicity (Table 25), and concentrations of chemical contaminants (Table 26-32) were included in the correlations with benthic infauna indices.

Benthic Infauna Indices vs. Grain Size and Total Organic Carbon

Typically, concentrations of trace metals tend to increase with increased percent fines, and high concentrations of organic compounds are related to higher total organic carbon (TOC) concentrations. Since higher concentrations of toxic compounds such as trace metals and organic compounds are generally expected to be related to decreased benthic community abundance and variability, higher concentrations of fines and organic carbon are also expected to be related to decreased abundance and diversity. Most of the indices of benthic infauna abundance and diversity followed the expected pattern, with statistically significant decreases correlated with increasing percent fine-grained particles and TOC content (Table 24). Taxa richness, Swartz's Dominance Index, mollusc abundance, and miscellaneous taxa abundance displayed the highest significant negative correlations with both percent fines and TOC (rho=-0.358 to -0.374, $p \leq 0.001$ and rho=-0.41 to -0.66, $p \leq 0.0001$). Inverse correlations were also apparent between total abundance vs. percent fines, evenness vs. TOC, and arthropod abundance vs. both percent fines and TOC, but at a lower level of significance (rho=-0.219, $p \leq 0.05$ and –0.26 to –0.316, $p \leq 0.01$). Relationships between total abundance vs. TOC, Pielou's evenness vs. percent fines, and annelid and echinoderm abundance vs. both percent fines and TOC were not significant.

Benthic Infauna Indices vs. Toxicity

Examination of Table 25 indicated the following relationships between benthic infauna indices and toxicity. None of the indices of benthic structure were significantly correlated with percent amphipod survival. Percent urchin fertilization showed a highly significant negative correlation with annelid abundance (rho=-0.391, $p \leq 0.0001$) and to a lesser extent with total abundance (rho=-0.29, $p \leq 0.01$). That is, as percent fertilization decreased in laboratory tests (i.e., increasing toxicity), the abundance of annelids and all organisms in the benthic samples increased. These negative correlations were counter to what would be expected, and may be related to very high numbers of toxicant-tolerant species of annelids, such as *Aphelochaeta*, in some of the samples.

Results of the microbial bioluminescence tests were positively correlated with taxa richness (rho=0.306, $p \leq 0.01$), Swartz's Dominance Index (rho=0.257, $p \leq 0.01$), and the abundance of molluscs (rho=0.286, $p \leq 0.01$), but negatively correlated with the abundance of echinoderms (rho=-0.285, $p \leq 0.01$). These correlations indicated that as Microtox™ EC50 values decreased (i.e., increasing toxicity), there were decreases in taxa richness, the numbers of species that were dominant, and the abundance of molluscs. Echinoderm abundance, however, decreased as toxicity decreased.

Benthic indices would be expected to decrease as cytochrome P450 HRGS induction increased (i.e., toxicity increased). Significant negative correlations were apparent for Pielou's Evenness Index (rho=-0.38, p<0.0001), Swartz's Dominance Index (rho=-0.351, p<0.001), and the abundance of arthropods (rho=-0.241, p<0.05) and miscellaneous taxa (rho=-0.319, p<0.01). However, as with the urchin fertilization results and counter to what would be expected, the abundance of annelids (rho=0.427, p<0.0001) and all organisms (rho=0.263, p<0.01) in the benthic samples increased significantly with increasing toxic responses. Again, these results may be related to very high numbers of toxicant-tolerant species of annelids, such as *Aphelochaeta*, in some of the samples.

Benthic Infauna Indices vs. Classes of Chemical Compounds

Spearman-rank correlations were calculated for benthic indices vs. concentrations of chemical groups normalized to their respective sediment guidelines (Table 26) to determine if they corresponded with each other. The data indicated that there was considerable correspondence between benthic measures and several groups of chemicals in the sediments. The chemical classes that were correlated with the benthic indices differed among the benthic endpoints and some correlations were positive while others were negative.

Total abundance, taxa richness, annelid abundance, and mollusca abundance all were positively correlated (to varying degrees) with mean SQS and CSL quotients for LPAH, HPAH, and total PAHs. Annelid abundance was also positively correlated with mean ERM quotients for chlorinated organic hydrocarbons, PAHs, and 25 compounds. Taxa richness, Pielou's evenness, Swartz's Dominance, and miscellaneous taxa abundance were significantly negatively correlated with mean ERM, SQS, and CSL quotients for metals. Pielou's evenness and Swartz's Dominance were also significantly negatively correlated with mean ERM quotients for chlorinated organic hydrocarbons, PAHs, and 25 compounds.

Benthic Infauna Indices vs. Individual Chemical Compounds

Measures of taxa richness were highly negatively correlated (p<0.0001) with many individual trace metals quantified with partial digestions (Table 27), decreasing with increasing concentrations of many metals, including those that are essential elements (e.g., calcium, iron, and sodium) and those that are potential toxins (e.g., cadmium, silver, and zinc). The correlation between taxa richness and selenium was the highest one observed (rho = -0.721, p<0.0001). All other indices showed primarily weaker and non-significant negative correlations with the concentrations of various partial digestion metals.

The correlations between benthic measures and concentrations of trace metals determined with total digestions often were weaker than those observed with partial digestions (Table 28). Taxa richness and Swartz's Dominance Index displayed the largest number of significant negative correlations with many of the same elements determined with partial digestions, including arsenic, cadmium, chromium, copper, lead, nickel, vanadium, and zinc. The majority of correlation results for the other indices showed weaker and non-significant negative correlations with the concentrations of various total digestion metals, including both essential and potentially toxic metals.

Table 29 summarizes the results of correlations between benthic indices and concentrations of individual and sums of LPAH compounds. While the majority of correlation results were nonsignificant, a few positive and negative significant correlation results were seen for the different indices. Annelid abundance displayed the greatest number of positive correlations when compared with these LPAH values.

Table 30 summarizes the results of correlations between benthic indices and concentrations of individual HPAH compounds. As with LPAH compounds, the majority of the correlation results were nonsignificant, although Peilou's evenness values were significantly negatively correlated, while annelid abundance values were strongly positively correlated with HPAH concentrations.

Correlations between benthic indices and concentrations of DDT isomers, PCB congeners and aroclors, organotins, phenols, and miscellaneous compounds showed few significant results (Tables 31 and 32). Pielou's evenness and Swartz's dominance displayed the majority of significant negative correlations with various PCBs, while taxa richness was strongly correlated with phenol (rho=-0.728, $p<0.0001$), and miscellaneous taxa abundance was strongly correlated with 4-methylphenol (rho=-0.503, $p<0.0001$).

Summary

The majority of benthic infaunal indices displayed a statistically significant inverse relationship with the percent of fine-grained particles and TOC content of the sediments, while a few (annelid and echinoderm abundance) showed non-significant relationships with these two sediment characteristics. Relationships between benthic indices and toxicity test results varied from one test to another. Benthic indices were not significantly correlated with percent amphipod survival. Abundance of annelids was strongly correlated with urchin fertilization success and the response of the cytochrome P450 HRGS bioassay, possibly in response to the presence of high numbers of toxicant-tolerant species of annelids, such as *Aphelochaeta*. Pielou's evenness was also strongly correlated with the cytochrome P450 HRGS bioassay. Correlations between benthic measures and groups of chemicals in the sediments indicated that differing suites of indices were correlated (to varying degrees) with mean ERM, SQS, and CSL quotients for metals, chlorinated organic hydrocarbons, and PAHs. Annelid abundance was strongly positively correlated with all but the metals quotients, while taxa richness and Swartz's Dominance were strongly negatively correlated with metals values. Correlations of benthic indices with individual chemical compound values again indicated that taxa richness was strongly correlated with metals values, while annelid abundance was again strongly correlated with HPAH values. No single chemical or chemical class was uniquely correlated with the measures of benthic structure. Rather, many different chemicals and chemical classes, obviously co-varying with each other, indicated strong associations with many of the benthic measures of abundance and diversity. This observation was similar to that for the data from the toxicity tests, that is, indicative of the presence of complex mixtures correlated with toxicity.

Triad Synthesis: A Comparison of Chemistry, Toxicity, and Infaunal Parameters

To generate a more comprehensive picture of the quality of the sediments throughout the study area, a weight-of-evidence approach was used to simultaneously examine all three sediment “triad” parameters measured. Data from the toxicity testing, chemical analyses, and benthic community analyses from all stations were combined into one table (Appendix H) for review.

From this data compilation, thirty-six stations were identified in which at least one chemical concentration exceeded an ERM, SQS, or CSL value and at least one of the toxicity tests indicated statistically significant results relative to controls (Table 33). These stations were located in Port Townsend (1), the central basin (3), the Bainbridge Basin (2), Dyes Inlet (2), Sinclair Inlet (6), and Elliott Bay and the Duwamish River (22). Together, these stations represented an area of 99.73 km^2 or about 14% of the total survey area.

Twenty-five stations showed no indications of significant sediment toxicity or chemical contamination (Table 34). These stations were located in Port Townsend (1), Admiralty Inlet (3), Possession Sound (2), the central basin (3), Port Madison (3), Liberty Bay (3), the Bainbridge Basin (4), Rich Passage (3), Dyes Inlet (1), and outer Elliott Bay (2). These 25 stations represented an area of 359.31 km^2, equivalent to 49% of the total survey area. Both sets of stations are highlighted in Figures 38-42.

The remaining thirty-nine stations displayed either signs of significant chemical contamination but no toxicity, or significant toxicity, but no chemical contamination. These stations were located in Port Townsend (4), Possession Sound (1), the central basin (10), Eagle Harbor (3), Liberty Bay (3), the Bainbridge Basin (6), and Elliott Bay and the Duwamish River (12). Together, these stations represented an area of 272.62 km^2, equivalent to 37% of the total central Puget Sound study area.

The complete suite of triad parameters for all stations was examined to determine whether the infaunal assemblages, as characterized by benthic indices, appeared to be impacted by the presence or absence of toxic compounds. Details regarding the “triad” relationship for all 100 stations are summarized below.

Examination of the six stations from the two strata in Port Townsend indicated that one station, 106, had both significant toxicity results and elevated chemical contamination, and one station, 110, had no significant results. Sediments from stations 106-108 (stratum 1) and stations 109-111 (stratum 2), situated in southern and northern Port Townsend respectively (Figure 38), were collected from depths ranging from 13-34m, with sediment types ranging from primarily sand to primarily silt-clay particles. All (with the exception of station 110) had levels of 4-methylphenol above state SQS and CSL criteria. No toxicity was displayed at these stations, with the exception of significantly reduced amphipod survival at station 106. Measures of infaunal diversity at these 6 stations were, in most cases, high and similar between stations, with little similarity in the dominant species list from station to station. Station 106, which displayed both impacted toxicity and chemical measures, also displayed the lowest total abundance (302 individuals), but exhibited a relatively high SDI (20). Several of the 10 numerically dominant species were those known to be pollution tolerant, including *Paraprionospio pinnnata*, *Scoletoma luti*, and *Prionospio steenstrupi*, but the overall numbers of these organisms were low. Examination of the triad of data for station 106 does not strongly suggest pollution impact at this station.

In the six large strata (strata 4-6, 8,11,12) located in southern Admiralty Inlet through the central basin to the southern-most end of the study area, three of the 19 stations displayed both significant toxicity results and elevated chemical contamination (stations 123, 113, 140), while 7 stations had no significant results (stations 112, 116, 117, 119-121, 141) (Tables 33-34, Figures 38-40). Samples collected from stations 112, 116, and 117 (stratum 4) in south Admiralty Inlet (Figure 38), displayed no significant toxicity results or elevated chemical concentrations. The infaunal communities from these samples varied in composition, with the community sampled from station 112 (Oak Bay) differing from the communities sampled from stations 116 and 117 (Useless Bay), which were very similar to one another. Community differences are probably associated with differing natural conditions including station depths (station 112-25m; station 116, 117-64 and 45m, respectively), grain size (station 112-28 % fines; station 116,117- 5% and 4% fines, respectively), and station proximity to one another. Most of the infaunal indices are similar for stations 116 and 117, and they share six of their 10 dominant species, while the indices are quite different at station 112, and no dominant species are shared with stations 116 and 117.

Similar to stratum 4, two of the samples (stations 119 and 120) collected from stratum 5, Possession Sound (Figure 38), which were in close proximity to one another, displayed no significant toxicity results or elevated chemical concentrations, and had similar infaunal index values. The sediments at both stations were sandy (6% and 5% fines, respectively), had similar highly diverse benthic indices, and shared 6 of 10 dominant species. The infaunal community from station 118 in stratum 5, geographically distant from stations 119 and 120, displayed a differing range of infaunal indices and shared no dominant species with the other two stations. Sediments from this station did have levels of 4-methylphenol exceeding both state criteria, but the difference in infaunal assemblage structure could be attributed to the differing sediment type at station 118 (92% fines), rather than chemical contamination. All three stations were at similar depth ranges (190-211m).

In general, examination of the infaunal community structure in sediments collected from Port Townsend through Admiralty Inlet and Possession Sound revealed no clear patterns related to chemistry and or toxicity data. Instead, similarities of infaunal indices and species composition between stations appeared to be related to similarity in station depth, grain size, and geographic proximity of stations.

The next four strata results presented (6, 8, 11, and 12), include 13 stations that were located in Puget Sound's central basin (Figures 39 and 40). While the majority of these stations were located in deep water (190-250m) and were composed of primarily silt-clay sediment particles (81-98% fines), a few were shallower and/or had more mixed sediments. Three stations (123, 113, and 140) in these central basin strata had sediments with some degree of both chemical contamination and toxicity.

Stratum 6, in Puget Sound's central basin (Figure 39), included stations 121-123, with levels of 4-methylphenol exceeding both state criteria at stations 122 and 123, and significant reduction in amphipod survival at station 123. Comparison of infaunal assemblages between stations indicated similarities in species composition at stations 122 and 123, collected from 200-220 m depth. Sediments from both of these deep stations were composed of 86% fines. Assemblages from these two stations shared 6 of 10 dominant species and had relatively similar infaunal indices. The infaunal indices generated for station 121, located in 10 m of water, with sediments composed of 5% fines, differed from the other two stations. Station 121 had a higher total abundance of 1272 (verses 240 and 314 for stations 122 and 123, respectively), higher abundance of arthropods (677) and molluscs (475) (verses 53/92 and 127/147 for stations 122 and 123, respectively), and no dominant species shared with stations 122 and 123 in this stratum. There was no clear association between triad parameters at station 123, rather, it appeared that the infaunal assemblage at this station was structured by depth and grain size.

Four samples were collected in stratum 8, near West Point (Figure 39), in depths ranging from 168m to 239m. Sediment from these stations ranged from a mixed grain-size composition (42% and 72% silt-clay – stations 129 and 128, respectively) to silt-clay (85% and 90% silt-clay – stations 113 and 127, respectively). Infaunal composition was more similar between stations 127-129 than in station 113, which had the lowest total, annelid, arthropod, and mollusc abundance. Station 113 did have levels of 4-methylphenol exceeding both state criteria, and displayed significant cytochrome P450 HRGS toxicity response.

The three stations (136-138) collected from 213-250m in Puget Sound's central basin (stratum 11) (Figure 40) were homogeneous in sediment composition (81-94% fines), toxicity (all displayed significant cytochrome P450 HRGS toxicity response), chemistry (no chemical concentrations in the sediments exceeded state or national guidelines), and infaunal indices, displaying moderate total abundance and taxa richness values and sharing 6 out of 10 dominant species. There was no clear association among triad parameters at these stations.

The final three stations (139, 140, and 141) collected from Puget Sound's central basin (stratum 12) (Figure 40) were quite dissimilar from one another, being collected at differing depths (235m, 190m, and 97m, respectively) and possessing differing grain sizes (54%, 98%, and 12% fines, respectively). Station 139 and 140 displayed significant cytochrome P450 HRGS toxicity response and shared 7 of their 10 dominant species, although infaunal indices between the two stations differed. Station 140 also displayed chemical contamination (4-methylphenol concentration measured above both state and national guidelines). Station 141, located the farthest south of the three stations, displayed very different infaunal indices and species composition, and had no significant toxicity results or elevated chemical concentrations. No clear relationships could be seen among the three triad parameters at station 140.

As with the more northern stations in this study area, examination of the benthic infaunal community structure in sediments collected from Puget Sound's central basin stations revealed no clear patterns related to chemistry or toxicity data. Instead, similarities of infaunal indices and species composition among stations appeared to be correlated with similarity in station depth, grain size, and distance between stations.

Examination of the next three strata (7, 9, and 10) including three smaller, shallow embayments adjacent to the central basin (Figures 39 and 40), revealed no stations in which all three triad parameters appeared to be impacted. None of the three stations (124-126) located in Port Madison (stratum 7) (Figure 39) displayed any toxicity or chemical contamination. These stations were located at 28-45m depth, and were comprised of silty-sand (14-26% fines). Infaunal communities were both abundant (637-852 individuals) and taxa rich (73-93 total taxa), and shared 9 of their 10 dominant species.

Sediments from stations 130-132, located in stratum 9, Eagle Harbor (Figure 40), were collected from 11-14m depths, and ranged in composition from silty sand (station 132, 20% fines) to mixed sediments (stations 130 and 131, 44% and 80% fines, respectively). All three stations displayed significant toxicity with the cytochrome P450 HRGS assay, but no chemicals exceeded state or national guidelines. Sediment from these stations however, did exhibit strong petroleum (from all 3 stations) and sulfur (from stations 131-132, only) odors, and were olive gray in color, indicating possible chemical contamination and/or anoxic conditions. Infaunal indices showed few consistencies among the three stations, although the benthic infaunal assemblages did share 3 of their 10 dominant species, including the pollution-tolerant polychaete, *Aphelochaeta* sp. N1. Although it is possible that the infaunal communities were responding to some type of unmeasured chemical contaminant or adverse natural condition (e.g., low dissolved oxygen) in the sediments, and/or were associated with the significant toxicity displayed, the triad of evidence pointing to pollution-impacted stations was not complete at these three stations.

The three shallow stations (stations 133-135; 27 – 47 m depth) in stratum 10, to the south and west of Blake Island (Figure 40), were composed of predominantly silt and clay particles (81-94% fines). None of the three stations had chemical concentrations in the sediments exceeding state or national guidelines, although station 134 displayed significantly reduced amphipod survival, and station 135 displayed significant cytochrome P450 HRGS toxicity response. No clear pattern of correspondence could be seen between these parameters and the infaunal assemblage composition, with all three stations possessing relatively abundant and taxa rich assemblages, and sharing 4 of their dominant species.

Examination of the thirty stations from the 10 strata west of Bainbridge Island, including Liberty Bay, and Dyes and Sinclair Inlets, indicated that ten stations (stations 148, 151, 160-165, 170, 171) had both significant toxicity results and elevated chemical contamination. Eight of these ten stations were located in Dyes and Sinclair Inlets. Eleven of these thirty stations (stations 142, 145, 147, 149, 150, 152, 154-156, 166, 169) had no significant results; none were located in Sinclair Inlet, and only one in Dyes Inlet (Figures 39, 41).

Examination of stations in strata 15 and 16 (west of Bainbridge Island) (Figures 39 and 41) indicated high levels of 4-methylphenol and benzyl alcohol at stations 148 and 151, respectively. Both stations also displayed significant toxicity with the cytochrome P450 HRGS assay. Depths of the 6 stations in these two strata were shallow, ranging from 6 to 35m. Sediment types for these stations included silt-clay at stations 148, 151, and 153 (90%, 95%, and 87% fines, respectively), mixed at station 150 (51% fines), silty sand at station 152 (22 % fines), and sand at station 149 (6% fines). Infaunal indices and dominant species composition (i.e., 5 shared dominant species) were similar among the three stations with silt-clay sediments, suggesting that grain size, rather than the toxicity and chemical composition of the sediments, had a large influence on community structure at these stations. In addition, station 148 (90% fines, significant chemistry and toxicity) displayed infaunal indices and species composition (i.e., sharing 8 of 10 dominant species) similar to station 150 (51% fines), which had no significant toxicity results or elevated chemical concentrations. Stations 149 (6% fines) and 152 (22 % fines) displayed no significant toxicity results or elevated chemical concentrations, and little similarity to any of these 6 stations in their community composition and infaunal indices, probably due to their sediment grain size composition.

The sediments from all six stations (160-165) in strata 19 and 20 (Sinclair Inlet) were composed primarily of silt-clay (87-96% fines), and were collected from 8.6 to 13.5m depths. These sediments also had a strong sulfur smell, and were gray to black in color, possibly indicating anoxic conditions. All stations exhibited mercury concentrations exceeding state and, with the exception of station 161, national standards, accompanied by significant toxicity with the cytochrome P450 HRGS assay at all stations, and significantly reduced urchin fertilization at stations 160 and 165. All of the stations had relatively high benthic infaunal abundance (except for station 160, which also had the highest toxicity level based on percent urchin fertilization) and relatively high taxa richness, but low Swartz's Dominance Index (2-7 taxa). The benthic communities at stations 160, 161, 163, and 164 were dominated by *Aphelochaeta* species N1. At station 160, however, total abundance and abundance of all taxa groups was significantly reduced. Stations 162 and 165 were dominated by *Eudorella pacifica* and *Amphiodia* species. These 3 taxa, along with the decapod crustacean *Pinnixa schmitti*, were present in 5 of the 6 stations in Sinclair Inlet. It is possible that the composition of the infaunal communities at these 6 stations, dominated by these 4 taxa, was a result of adverse chemical and toxicological impact from the sediments at these stations, indicating triad support for classification of these stations as impacted by pollution. It is also possible, however, that the infaunal composition at these stations was the result of other environmental factors that have not been measured, such as naturally occurring anoxic conditions in the sediments. In comparison, station 131, in Eagle Harbor, possessed many characteristics similar to the stations in Sinclair Inlet, including olive gray sediments with a strong sulfur odor, shallow depth (11m), high percent fines (80%), significant toxicity with the cytochrome P450 HRGS assay, and relatively high benthic infaunal abundance and taxa richness but low Swartz's Dominance Index (8 taxa). The dominant species list included both *Aphelochaeta* sp. N1 and *Eudorella pacifica*. No chemistry concentrations exceeded state or national standards, however, unlike the stations in Sinclair Inlet, which might indicate that the possible anoxic conditions at these stations were a naturally occurring factor influencing community structure.

Stratum 21, located in the Port Washington Narrows (Figure 41), contained three stations (166-168) in 18m, 8.2m, and 26m of water, respectively. Sediments at stations 166 and 167 consisted primarily of sand (7% and 8% fines, respectively), while station 168 consisted of silty sand (35% fines) and had a strong sulfur smell. Station 166 displayed no significant toxicity results or elevated chemical concentrations, while station 167 had highly significant amphipod mortality and urchin fertilization was significantly reduced. Station 168 displayed both significant urchin and cytochrome P450 HRGS toxicity results. Stations 166 and 167 shared similar infaunal indices, possibly due to their similar sediment grain size composition. All three stations shared two dominant taxa, the mollusc *Alvania compacta* and the polychaete *Aphelochaeta* sp. N1. In station 168, as with two of the stations in Sinclair Inlet, *Aphelochaeta* sp. N1 was found in high numbers (1023) in a shallow station with a strong sulfur odor, although this station had lower percent fines (35%) than those in Sinclair Inlet (93% and 87%). *Aphelochaeta* sp. N1 was also found in sandy stations 166 and 167, but in much lower densities (29 and 100 individuals, respectively). Conversely, *Alvania compacta* was found in higher densities at the two sandy stations (79 and 193, respectively), and in lower numbers (35 individuals) at the silty sand station. Although there are similarities in the significant toxicity measures and infaunal indices and species composition among station 168 and stations 161 and 164 in Sinclair Inlet, the lack of significant chemistry results does not provide a clear association among triad parameters at these stations. However, as was speculated for the data from Sinclair Inlet, it is possible that other environmental measures such as dissolved oxygen concentrations in the sediment pore water and overlying waters may play a role in influencing infaunal community composition at this station.

The three stations in stratum 22, Dyes Inlet (169-171) (Figure 41), consisted of one station (169) with no significant toxicity results or elevated chemical concentrations, and two stations with both significant levels of chemical contamination and toxicity results. The sample from station 169, collected from 7m, was primarily sandy (8% fines), had no significant toxicity results or elevated chemical concentrations, and displayed extremely high total abundance and species richness. The high total abundance (1123 individuals) was due primarily to a large abundance of the polychaetes *Phyllochaetopterus prolifica* (455 individuals), *Circeis* sp. (240 individuals), and a small number of *Aphelochaeta* sp. N1 (137 individuals).

Stations 170 and 171, located in approximately 13.5m depths, both were composed of a high percent silt clay (93 and 88% fines, respectively), and both had dark olive gray or brown sediments with a strong sulfur smell. Both stations had significant levels of chemical compounds (benzyl alcohol and either nickel or mercury), and displayed significant cytochrome P450 HRGS toxicity results. These two stations shared 8 of 10 dominant species, including the same four species that dominated the stations in Sinclair Inlet, the crustaceans *Pinnixa schmitti* and *Eudorella pacifica*, the brittle star *Amphiodia urtica/periercta* complex, and the polychaete *Aphelochaeta* sp. N1. Similar to station 165 in Sinclair Inlet, the crustacea and brittle stars dominated the two contaminated and toxic stations in Dyes Inlet, with a much-reduced number of *Aphelochaeta* sp. N1 present. As with station 165, it is possible that the composition of the infaunal communities at these two stations, dominated by these four taxa, is a result of the relatively high contamination and toxicity in the sediments at these stations, indicating triad support for classification of these stations as affected by pollution. It is also possible, however, that the infaunal composition at these stations may be the result of other environmental factors existing at these stations that have not been measured, such as naturally occurring anoxic conditions in the sediments. Alternatively, benthic community effects may also be due to an unmeasured chemical, or a combination of chemicals that were measured at lower levels.

Examination of the thirty-six stations from the 10 strata in Elliott Bay and the Duwamish indicated that 22 stations, located primarily along the bay’s northeastern shoreline, in both the east and west waterways around Harbor Island, and in the Duwamish Waterway, had both significant toxicity results and elevated chemical contamination. Only two of these thirty-six stations (stations 175 and 178, both in outer Elliott Bay) had no significant toxicity results and no elevated chemical contamination (Figure 42).

Eight samples collected along the shoreline of Elliott Bay (115, 176, 179-184) had highly contaminated and relatively toxic sediments. Sediment guidelines for mercury, several PAHs, butyl benzyl phthalate and 4-methylphenol were exceeded in one or more of these stations. The most extreme case was the sediment from station 184, which exceeded seven ERM and seven SQS values. At all eight stations, significant toxicity was observed in at least two of the tests. Cytochrome P450 HRGS enzyme induction was very high (>107µg/g) at stations 115 and 182-184, and the urchin fertilization tests were significant at all stations except 181. Despite the presence of relatively high chemical concentrations and the occurrence of toxicity in the laboratory tests, the benthic indices suggested an abundant and diverse benthic community at seven of these eight stations (i.e., all except station 115). Total abundance at these seven stations ranged from 457 to 876; taxa richness ranged from 69 to 113. Evenness values were between 0.731 to 0.833, while the Swartz's Dominance Index (SDI) values ranged from 12 to 27. Many of the dominant species, however, were organisms known for their tolerance to pollution, including *Parvilucina tenuisculpta*, *Euphilomedes producta*, *Scoletoma luti*, *Axinopsida serricata*, *Prionospio steenstrupi*, and *Aphelochaeta* species N1. The infaunal community at station 115 had both significant chemistry and toxicity results, and an infaunal community composition which suggested triad support for classification of this station as impacted by pollution. Total abundance at this station was higher than at the other shoreline stations (1161 individuals), but taxa richness was depressed (43 taxa), and evenness and SDI values were extremely low (0.255, 1 taxon). The infaunal community was dominated by the pollution-tolerant polychaete *Aphelochaeta* sp. N1, had no echinoderms or miscellaneous taxa, and very few arthropods.

Relatively high chemical concentrations occurred in five of the twelve stations in the middle of Elliott Bay (185, 186, 188, 194, and 196). Up to five sediment guidelines were exceeded at each of these stations, and mean ERM quotients ranged from 0.4 to 1.5. Among these five stations, the sediments at station 188 were most contaminated, primarily with several PAHs. The mean ERM quotient in this sample was 1.5. Cytochrome P450 HRGS enzyme induction was significantly high (20 to 153 µg/g) in all five samples, but none of the other toxicity tests had significant results. Total abundance, taxa richness, evenness, and SDI values for two of these stations (stations 185 and 186) were relatively high, indicating moderately abundant and diverse communities, with 3 species shared between the stations' top 10 dominant species, including *Axinopsida serricata*, *Euphilomedes producta*, and *Levinsenia gracilis*. These two stations displayed infaunal community structure that appeared to be only modestly influenced by the chemical and/or toxicological contamination of the sediments. The other 3 stations in mid-Elliott Bay, however, displayed infaunal indices that are more strongly suggestive of possible triad correspondence with the chemistry and toxicity results. The infaunal indices at stations 188, 194, and 196 displayed high total abundance and taxa richness values (456-825, and 42-67, respectively), but lowered evenness and SDI values (0.451-0.539, and 2-5), and supported communities with 4 shared dominant species, including *Axinopside serricata*, *Levinsenia gracilis*, *Aricidea lopezi*, and *Scoletoma luti*. There also were few arthropods and echinoderms (i.e., the typically more pollution-sensitive taxa) in these samples.

All seven stations sampled in the vicinity of Harbor Island (114, 197-202) had elevated concentrations of trace metals and/or a number of organic compounds and other toxicants. Toxicity was significant in the amphipod survival at station 202 (90.11% of controls), in the urchin fertilization test for stations 197 and 199-201(62-73% of controls), and in the cytochrome P450 HRGS assays for all seven stations (96.6 – 153.5 µg/g). The cluster of three stations at the mouth of the western fork of the Duwamish River (stations 197-199) were similar in their infaunal community composition, with high abundance and taxa richness values (806-1391, and 71-90, respectively), and moderately high evenness and SDI values (0.633-0.679, and 9-12, respectively. Infaunal assemblages at these stations shared only two species from the dominant species, including *Euphilomedes carcharodonta* and *Parvilucina tenuisculpta*. The more diverse and abundant infaunal assemblages at these three stations do not strongly support the triad of sediment parameters suggesting pollution-induced degradation at these stations. The benthic communities at station 114 and at the three East Harbor Island stations (200-203), however, all provide better support for the triad weight-of-evidence suggestion of pollution-induced degradation at these stations. Benthic assemblages at these four stations supported high abundance and richness values (980-1572, and 42-57 taxa, respectively), but low evenness and SDI values (0.386-0.598, and 2-5, respectively). Numbers of pollution-sensitive taxa, including arthropods and echinoderms were low (21-37 arthropod taxa) or absent (0 echinoderms) in these samples. Infauna abundance was high in all four samples due primarily to very high numbers of pollution-tolerant species including *Aphelochaeta* species N1, *Heteromastus filobranchus*, *Scoletoma luti*, and *Axinopsida serricata*.

In the Duwamish, two of the three stations (204 and 205) had significant levels of chemical contamination and toxicity. These stations had high concentrations of up to 7 toxicants, including PCBs, HPAHs, 4-methylphenol, pentachlorophenol, and butylbenzylphthalate. Cytochrome RGS values were significantly elevated (47 – 77) at these two stations. As with the 4 stations around Harbor Island, these two stations had abundant benthic infauna (1155-1561) and high taxa richness values (52-65), but lowered evenness (0.373-0.454) and SDI (2-3) values. The infaunal communities at these stations were composed of high numbers of the pollution-tolerant species *Aphelochaeta* species N1, *Scoletoma luti*, and *Nutricola lordi*. Again, the triad weight-of-evidence appears to support the identification of pollution induced degradation at these two stations.

In total, it appeared that 18 of the 36 stations in which both chemistry and toxicity measures were significantly elevated also possessed benthic infaunal assemblage structure that may have been influenced by the chemical and toxicological parameters measured at each station. These 18 stations were located in Sinclair Inlet (6), Dyes Inlet (2), Elliott Bay (4), in the waterways west (1) and east (3) of Harbor Island, and in the lower Duwamish River (2). These 18 stations represented an area 8.1 km^2, or about 1.1% of the total survey area.

Summary

A review of the compiled set of triad data of toxicity, chemistry, and benthic infauna indicated that of the 100 stations sampled, 36 had sediments with significant toxicity and elevated chemical contamination. These stations were located in Port Townsend (1), the central basin (3), the Bainbridge Basin (2), Dyes Inlet (2), Sinclair Inlet (6), and Elliott Bay and the Duwamish River (22). Together, these stations represented an area of 99.73 km^2 or about 14% of the total survey area. Of these 36 stations, 18 appeared to have benthic communities that were possibly affected by chemical contaminants in the sediments. They included stations 160-165 (Sinclair

Inlet), 170-171 (Dyes Inlet), 115 (Shoreline Elliott Bay), 188, 194, and 196 (Mid-Elliott Bay), 114 (West Harbor Island), 200-202 (East Harbor Island), and 204 and 205 (Duwamish River). These stations typically had moderate to very high total abundance, including high numbers of *Aphelochaeta* species N1 and other pollution-tolerant species, moderate to high taxa richness, low evenness, and low Swartz's Dominance Index values. Often, pollution-sensitive species such as arthropods and echinoderms were low in abundance or absent from these stations. These 18 stations represented an area of 8.1 km^2, or about 1.1% of the total survey area. Twenty-five stations were identified with no indications of significant sediment toxicity or chemical contamination (Table 34). All of the benthic indices at these stations indicated abundant and diverse populations of most or all taxonomic groups. Arthropods were abundant in all samples; however, echinoderms were not found in a few of these samples. These stations were located in Port Townsend (1), Admiralty Inlet (3), Possession Sound (2), the central basin (3), Port Madison (3), Liberty Bay (3), the Bainbridge Basin (4), Rich Passage (3), Dyes Inlet (1), and outer Elliott Bay (2). These 25 stations represented an area of 359.3 km^2, equivalent to approximately 49% of the total survey area. The remaining thirty-nine stations displayed either signs of significant chemical contamination but no toxicity, or significant toxicity, but no chemical contamination. In the majority of these samples, the benthic populations were abundant and diverse, and represented the types of biota expected in the habitats that were sampled. These stations were located in Port Townsend (4), Possession Sound (1), the central basin (10), Eagle Harbor (3), Liberty Bay (3), the Bainbridge Basin (6), and Elliott Bay and the Duwamish River (12). Together, these stations represented an area of 272.6 km^2, equivalent to approximately 37% of the total central Puget Sound study area.

Discussion

Spatial Extent of Toxicity

The survey of sediment toxicity in central Puget Sound was similar in intent and design to those performed elsewhere by NOAA in many different bays and estuaries in the U. S. using comparable methods and to the survey conducted in northern Puget Sound (Long et al., 1999a). Data have been generated for areas along the Atlantic, Gulf of Mexico, and Pacific coasts to determine the presence, severity, regional patterns and spatial scales of toxicity (Long et al., 1996). Spatial extent of toxicity in other regions ranged from 0.0% of the area to 100% of the area, depending upon the toxicity test.

The intent of this survey of central Puget Sound was to provide information on toxicity throughout all regions of the study area, including a number of urbanized/industrialized areas. The survey area, therefore, was very large and complex. This survey was not intended to focus upon any potential discharger or other source of toxicants. The data from the laboratory bioassays were intended to represent the toxicological condition of the survey area, using a battery of complimentary tests. The primary objectives were to estimate the severity, spatial patterns, and spatial extent of toxicity, chemical contamination, and to characterize the benthic community structure. A stratified-random design was followed to ensure that unbiased sampling was conducted and, therefore, the data could be attributed to the strata within which samples were collected.

Four different toxicity tests were performed on all the sediment samples. All tests showed some degree of differences in results among the test samples and negative controls. All showed spatial patterns in toxicity that were unique to each test, but also overlapped to varying degrees with results of other tests. There were no two tests that showed redundant results.

Amphipod Survival – Solid Phase

These tests of relatively unaltered, bulk sediments were performed with juvenile crustaceans exposed to the sediments for 10 days. The endpoint was survival. Data from several field surveys conducted along portions of the Pacific, Atlantic, and Gulf of Mexico coasts have shown that significantly diminished survival of these animals often is coincident with decreases in total abundance of benthos, abundance of crustaceans including amphipods, total species richness, and other metrics of benthic community structure (Long et al., 1996). Therefore, this test often is viewed as having relatively high ecological relevance. In addition, it is the most frequently used test nationwide in assessments of dredging material and hazardous waste sites.

The amphipod tests proved to be the least sensitive of the tests performed in central Puget Sound. Of the 100 samples tested, survival was significantly different from controls in 7 samples. Samples in which test results were significant were collected at stations widely scattered throughout the study area. The data showed no consistent spatial pattern or gradient in response among contiguous stations or strata. There was one sample in which survival was statistically significant and mean survival was less than 80% of controls; the response level was determined empirically to be highly significant (Thursby et al., 1997).

The results in the amphipod tests performed in central and northern Puget Sound differed from those developed in studies with *A. abdita* conducted elsewhere in the U.S. The frequency distributions of the data from both areas are compared to that for data compiled in the NOAA/EMAP national database (Table 35). Whereas amphipod survival was less than 80% of controls in 12.4% of samples from studies performed elsewhere, only one of the samples from central Puget Sound showed survival that low. None of the northern Puget Sound samples indicated survival of less than 80%. In the national database 47% of samples indicated survival of 90-99.9%. Similarly, in central Puget Sound 48% of samples had survival within the range of 90-99.9%. In northern Puget Sound, 76% of samples showed comparable survival. In both Puget Sound areas, the lower "tail" of the distribution (i.e., samples in which survival was very low) was absent.

With the results of the amphipod tests weighted to the sizes of the sampling strata within which samples were collected, the spatial scales of toxicity could be estimated. A critical value of <80% of control response was used to estimate the spatial extent of toxicity in this test. However, because only one of the test samples indicated less than 80% survival relative to controls, the spatial extent of toxicity was estimated as 0.1% of the central Puget Sound survey area.

To add perspective to these data, the results from central and northern Puget Sound were compared to those from other estuaries and marine bays surveyed by NOAA in the U.S. The methods for collecting and testing the samples for toxicity were comparable to those used in the Puget Sound surveys (Long et al., 1996). In surveys of 26 U. S. regions, estimates of the spatial extent of toxicity ranged from 0.0% in many areas to 85% in Newark Bay, NJ (Table 36). The central and northern Puget Sound areas were among the many regions in which the spatial extent of toxicity in the amphipod tests was estimated to be 0% to 0.1%. With the data compiled from studies conducted through 1997, the samples that were classified as toxic represented about 5.9% of the combined area surveyed. The data for both regions of Puget Sound fell well below the national average. These data suggest that acute toxicity as measured in the amphipod survival tests was neither severe nor widespread in in sediments from the northern and central Puget Sound study areas.

Sea Urchin Fertilization - Pore Water

Several features of the sea urchin fertilization test combined to make it a relatively sensitive test (Long et al., 1996). In these tests, early life stages of the animals were used. Early life stages of invertebrates often are more sensitive to toxicants than adult forms, mainly because fewer defense mechanisms are developed in the gametes than in the adults. The test endpoint - fertilization success - is a sublethal response expected to be more sensitive than an acute mortality response. The gametes were exposed to the pore waters extracted from the samples; the phase of the sediments in which toxicants were expected to be highly bioavailable. This test was adapted from protocols for bioassays originally performed to test wastewater effluents and has had wide application throughout North America in tests of both effluents and sediment pore waters. The combined effects of these features was to develop a relatively sensitive test - much more sensitive than that performed with the amphipods exposed to solid phase sediments.

In central Puget Sound, the strata in which toxicity was highly significant (i.e., <80% of controls) totaled about 0.7%, 0.2%, and 0.6% of the total area in tests of 100%, 50%, and 25% porewater concentrations, respectively. These estimates are slightly lower than those calculated for the northern Puget Sound area where the estimated areas were 5.2%, 1.5% and 0.8% of the total, respectively.

NOAA estimated the spatial extent of toxicity in urchin fertilization or equivalent tests performed with pore water in many other regions of the U. S. (Long et al., 1996). These estimates ranged from 98% in San Pedro Bay (CA) to 0.0% in Leadenwah Creek (SC) (Table 37). As in the amphipod tests, northern Puget Sound ranked near the bottom of this range, well below the "national average" of 25% calculated with data accumulated through 1997. Equivalent results in this test were reported in areas such as St. Simons Sound (GA), St. Andrew Bay in western Florida, and Leadenwah Creek (SC), in which urbanization and industrialization were restricted to relatively small portions of the estuaries. Therefore, as with the amphipod tests, these tests indicated that acute toxicity was neither widespread nor severe in sediments from the northern and central Puget Sound study areas.

Microbial Bioluminescence (Microtox™) - Organic Solvent Extract

The Microtox™ tests were performed with organic solvent extracts of the sediments. These extracts were intended to elute all potentially toxic organic substances from the sediments regardless of their bioavailability. The tests, therefore, provide an estimate of the potential for toxicity attributable to complex mixtures of toxicants associated with the sediment particles, which normally may not be available to benthic infauna. This test is not sensitive to the presence of ammonia, hydrogen sulfide, fine-grained particles or other features of sediments that may confound results of other tests. The test endpoint is a measure of metabolic activity, not acute mortality. These features combined to provide a relatively sensitive test - usually the most sensitive test performed nationwide in the NOAA surveys (Long et al., 1996).

In northern Puget Sound, the data were difficult to interpret because of the unusual result in the negative control sample from Redfish Bay (TX). Test results for the control showed the sample to be considerably less toxic relative to previous tests of sediments from that site and to tests of negative control sediments from other sites used in previous surveys. Therefore, new analytical tools were generated with the compiled NOAA data to provide a meaningful critical value for evaluating the northern Puget Sound data (Long et al., 1999a).

Using a critical value of <0.51 mg/ml, it was estimated that the spatial extent of toxicity in the central Puget Sound represented 0% of the survey area. This estimate ranked central Puget Sound at the bottom of the distribution for data generated from 18 bays and estuaries surveyed by NOAA (Table 38). This estimate for central Puget Sound (0%) was less than the estimate for northern Puget Sound (1.2% of the study area). Also, it was considerably less than the estimate for the combined national estuarine average of 39% calculated with data compiled through 1997.

Human Reporter Gene System (Cytochrome P450) Response - Organic Solvent Extract

This test is intended to identify samples in which there are elevated concentrations of mixed-function oxygenase-inducing organic compounds, notably the dioxins and higher molecular weight PAHs. It is performed with a cultured cell line that provides very reliable and consistent results. Tests are conducted with an organic solvent extract to ensure that potentially toxic organic compounds are eluted. High cytochrome P450 HRGS induction may signify the presence of substances that could cause or contribute to the induction of mutagenic and/or carcinogenic responses in local resident biota (Anderson et al., 1995, 1996).

In central Puget Sound, the cytochrome P450 HRGS assay indicated that samples in which results exceeded 11.1 and 37.1 μg/g B(a)P equivalents represented approximately 32.3% and 3.2%, respectively, of the total survey area. In contrast, the equivalent estimates for northern Puget Sound were 2.6% and 0.03% of the study area (Long et al., 1999a). Relatively high responses were recorded in many samples from large strata sampled in central Puget Sound, thereby resulting in larger estimated areas. In northern Puget Sound the samples with elevated responses were collected primarily in the small strata in Everett Harbor.

These tests were performed in NOAA surveys in 8 estuaries where estimates of spatial extent could be made: northern and central Puget Sound (WA), northern Chesapeake Bay (MD), Sabine Lake (TX), Biscayne Bay (FL), Delaware Bay (DE), Galveston Bay (TX), and a collection of Southern California coastal estuaries (CA). Based upon the critical values of 11.1 and 37.1μg/g, the samples from central Puget Sound ranked third highest among the 8 study areas for which there are equivalent data (Table 39). Toxic responses greater than 11.1 μg/g were most widespread in samples from northern Chesapeake Bay and Southern California estuaries. Toxic responses greater than 37.1 μg/g were most widespread in northern Chesapeake Bay followed by Delaware Bay and central Puget Sound. In the central Puget Sound area, RGS responses greater than 11.1 μg/g were more widespread than in the combined national average (20%), whereas responses greater than 37.1 μg/g were less widespread than the national average of 9.2%.

In central Puget Sound, RGS assay responses ranged from 0.4 μg/g to 223 μg/g and there were 27 samples in which the responses exceeded 37.1 μg/g. In northern Puget Sound, responses ranged from 0.3 μg/g to 104.6 μg/g and only four samples had responses greater than 37.1 μg/g. In analyses of 30 samples from Charleston Harbor and vicinity, results ranged from 1.8 μg/g to 86.3 μg/g and there were nine samples with results greater than 37.1 μg/g. In the 121 samples from Biscayne Bay, results ranged from 0.4 to 37.0 μg/g B[a]P equivalents. Induction responses in 30 samples from San Diego Bay were considerably higher than those from all other areas. Assay results ranged from 5 μg/g to 110 μg/g B[a]P equivalents and results from 18 samples exceeded 37.1 μg/g in San Diego Bay. Responses in eight samples exceeded 80 μg/g.

The percentages of samples from different survey areas with cytochrome P450 HRGS responses greater than 37.1 μg/g were: 60% in San Diego Bay, 30% in Charleston Harbor, 27% in central Puget Sound, 23% in Delaware Bay, 11% in Sabine Lake, 4% in northern Puget Sound, 1% in Galveston Bay, and 0% in both Biscayne Bay and Southern California estuaries. Based upon data from all NOAA surveys (n=693, including central and northern Puget Sound), the average and median RGS assay responses were 23.3 µg/g and 6.7 µg/g, somewhat lower than observed in central Puget Sound - average of 37.6 µg/g and median of 17.8 µg/g.

The data from these comparisons suggest that the severity and spatial extent of enzyme induction determined in the RGS test were roughly equivalent to those determined as the national average. There were several survey areas in which toxicity was more severe and widespread and several areas in which it was less so. The responses were clearly more elevated than those in samples from northern Puget Sound.

Levels of Chemical Contamination

In central Puget Sound, there were 11 samples in which the mean ERM quotients exceeded 1.0. These samples represented an area of 3.6 km^2, or about 0.5% of the total survey area. In the northern Puget Sound study, none of the mean ERM quotients for 100 samples exceeded 1.0. In comparison, 6 of 226 samples (3%) from Biscayne Bay, FL, had mean ERM quotients of 1.0 or greater (Long et al., 1999b). Among 1068 samples collected by NOAA and EPA in many estuaries nationwide, 51 (5%) had mean ERM quotients of 1.0 or greater (Long et al., 1998).

In central Puget Sound, there were 21 samples in which one or more ERM values were exceeded. These samples represented an area of about 11.4 km^2 or 1.6% of the total area. In northern Puget Sound, there were 8 samples (8%) representing about 9.5 km^2 (or 1.2% of the total area) in which one or more ERMs were exceeded. In Biscayne Bay, 33 of 226 samples (15%) representing about 0.7% of the study area had equivalent chemical concentrations (Long et al., 1996b). In selected small estuaries and lagoons of Southern California, 18 of 30 randomly chosen stations, representing 67% of the study area, had chemical concentrations that exceeded one or more Probable Effects Level (PEL) guidelines (Anderson et al., 1997). In the combined NOAA/EPA database, 27% of samples had at least one chemical concentration greater than the ERM (Long et al., 1998). In the Carolinian estuarine province, Hyland et al. (1996) estimated that the surficial extent of chemical contamination in sediments was about 16% relative to the ERMs. In data compiled from three years of study in the Carolinian province, however, the estimate of the area with elevated chemical contamination decreased to about 5% (Dr. Jeff Hyland, NOAA). In data compiled by Dr. Hyland from stratified-random sampling in the Carolinian province, Virginian province, Louisianian province, northern Chesapeake Bay, Delaware Bay, and DelMarVa estuaries, the estimates of the spatial extent of contamination in which one or more ERM values were exceeded ranged from about 2% to about 8%.

Collectively, the chemical data indicated that most of the central Puget Sound sediment samples were not highly contaminated. Relative to effects-based guidelines or standards, relative to previous Puget Sound studies, and relative to data from other areas in the U.S., the concentrations of most trace metals, most PAHs, total PCBs, and most chlorinated pesticides were not very high in the majority of the samples. However, the concentrations of nickel, mercury, 4-methyl phenol, benzoic acid, some PAHs, and PCBs were relatively high in some samples.

The highest concentrations of mixtures of potentially toxic chemicals primarily occurred in samples from Elliott Bay and Sinclair Inlet, the two most highly urbanized and industrialized bays within the 1998 study area. Similarly, the sediments analyzed during the 1997 survey of northern Puget Sound indicated that chemical concentrations were highest in Everett Harbor, which was one of the most urbanized bays in that survey.

Toxicity/Chemistry Relationships

It was not possible to identify and confirm which chemicals caused toxic responses in the urchin fertilization, Microtox™, and RGS tests in the samples from either central or northern Puget Sound. Determinations of causality would require extensive toxicity identification evaluations and spiked sediment bioassays. However, the chemical data were analyzed to determine which chemicals may have contributed to toxicity.

Typically in surveys of sediment quality nationwide, NOAA has determined that complex mixtures of trace metals, organic compounds, and occasionally ammonia showed strong statistical associations with one or more measures of toxicity (Long et al., 1996). Frequently, as a result of the toxicity/chemistry correlation analyses, some number of chemicals will show the strongest associations leading to the conclusion that these chemicals may have caused or contributed to the toxicity that was observed. However, the strength of these correlations can vary considerably among study areas and among the toxicity tests performed.

In both central and northern Puget Sound, the data were similar to those collected in several other regions (e.g., the western Florida Panhandle, Boston Harbor, and South Carolina/Georgia estuaries). Severe toxicity in the amphipod tests was either not observed in any samples or was very rare, and, therefore, correlations with toxicity were not significant or were weak. However, correlations with chemical concentrations were more readily apparent in the results of the sublethal tests, notably tests of urchin fertilization and microbial bioluminescence, as conducted in Puget Sound.

The sea urchin tests performed on pore waters extracted from the sediments and the Microtox™ and RGS tests performed on solvent extracts showed overlapping, but different, spatial patterns in toxicity in central Puget Sound. Because of the nature of these tests, it is reasonable to assume that they responded to different substances in the sediments. The strong statistical associations between the results of the sea urchin and RGS tests and the mean ERM quotients for 25 substances provides evidence that mixtures of contaminants co-varying in concentrations could have contributed to these measures of toxicity. Percent sea urchin fertilization was statistically correlated with the guideline-normalized concentrations of all chemical classes of contaminants. Furthermore, the highly significant correlations between enzyme induction in the RGS assays and the concentrations of PAHs normalized to effects-based guidelines or criteria suggest that these substances occurred at sufficiently high concentrations to contribute to the responses.

The data showed that urchin fertilization was statistically associated with several trace metals (notably arsenic, lead, mercury, tin and zinc) some of which occurred at concentrations above their respective ERL and SQS levels. The data from the northern Puget Sound study indicated very similar results, i.e., urchin fertilization was highly correlated with the concentrations of many trace metals either analyzed with partial or total digestions. Similarly, fertilization success was strongly correlated with the concentrations of PCBs in both central and northern Puget Sound. However, urchin fertilization was highly correlated with the concentrations of both high and low molecular weight PAHs in central Puget Sound, but not in northern Puget Sound.

Because the solvent extracts would not be expected to elute trace metals, Microtox™ and RGS results were expected to show strong associations with concentrations of PAHs and other organic compounds. The data indicated that microbial bioluminescence decreased with increasing concentrations of most individual PAHs and most PCB congeners in the northern samples, but not in the central samples. Microtox™ results were correlated with benzoic acid in both areas. In both survey areas, RGS enzyme induction increased with increases in the concentrations of most of the organic compounds, notably including all of the individual PAHs, all classes of PAHs, and many of the PCBs, some pesticides, and dibenzofuran.

There were a few similarities between the two study areas in the relationships between benthic indices and chemical concentrations, but there were more differences. For example, the data indicated highly significant correlations between the guideline-normalized concentrations of trace metals and taxa richness in both areas. Also, Swartz's Dominance Index was highly correlated with trace metals and mean ERM quotients for 25 substances in both surveys. However, total abundance was correlated with PAHs in central Sound, but not in northern Sound sediments. The very high correlations observed between mollusc abundance and many chemical classes in northern Sound were not apparent in central Sound. In contrast, annelid abundance was correlated with many chemical classes in central Sound, but not in northern Sound.

There were almost no similarities between the two studies in the correlations between benthic indices and toxicity results. The highly significant correlation between echinoderm abundance and urchin fertilization in northern Puget Sound was not observed in central Sound. The significant correlation between cytochrome P450 HRGS induction and Pielou's Evenness Index was positive in northern sediments and negative in central sediments. Annelid abundance increased significantly with increasing cytochrome P450 HRGS induction and decreasing urchin fertilization in central Sound, but not in northern Sound samples.

Although the chemicals for which analyses were performed may have caused or contributed to the measures of toxicity and/or benthic alterations, other substances for which no analyses were conducted also may have contributed. Definitive determinations of the actual causes of toxicity in each test would require further experimentation. Similarly, the inconsistent relationships between measures of toxicity and indices of benthic structure suggest that the ecological relevance of the toxicity tests differed between the two regions of Puget Sound.

Benthic Community Structure, the "Triad" Synthesis, and the Weight-of-Evidence Approach

The abundance, diversity, and species composition of marine infaunal communities vary considerably from place to place and over both short and long time scales as a result of many natural and anthropogenic factors (Reish, 1955; Nichols, 1970; McCauley et al., 1976; Pearson and Rosenberg, 1978; Dauer et al., 1979; James and Gibson, 1979; Bellan-Santini, 1980; Dauer and Conner, 1980; Gray, 1982: Becker et al., 1990; Ferraro et al., 1991; Llansó et al.,1998b). Major differences in benthic communities can result from wide ranges in water depths, oxygen concentrations at the sediment-water interface, the texture (grain size) and geochemical composition of the sediment particles, porewater salinity as a function of proximity to a river or stream, bottom water current velocity or physical disturbance as a result of natural scouring or maritime traffic, and the effects of large predators. In addition, the composition of benthic communities at any single location can be a function of seasonal or inter-annual changes in larval recruitment, availability of food, proximity to adult brood stock, predation, and seasonal differences in temperature, freshwater runoff, current velocity and physical disturbances.

In this survey of central Puget Sound, samples were collected in the deep waters of the central basin, in protected waters of shallow embayments and coves, in scoured channels with strong tidal currents, and in the lower reaches of a highly industrialized river. As a result of these major differences in habitat, the abundance, diversity, and composition of benthic communities would be expected to differ considerably from place to place.

Analyses of the benthic macroinfauna in the central Puget Sound survey indicated that the vast majority of samples were populated by abundant and diverse infaunal assemblages. The numbers of species and organisms varied considerably among sampling locations, indicative of the natural degree of variability in abundance, community structure, and diversity among benthic samples in Puget Sound. Calculated indices of evenness and dominance showed variability equal to that for species counts and abundance.

With huge ranges in abundance, species composition, and diversity as a result of natural environmental factors, it is difficult to discern the differences between degraded and un-degraded (or “healthy”) benthic assemblages. Some benthic assemblages may have relatively low species richness and total abundance as a result of the effects of natural environmental factors. There were a number of stations in which the benthos was very abundant and diverse despite the presence of high chemical concentrations and high toxicity.

Both Long (1989) and Chapman (1996) provided recommendations for graphical and tabular presentations of data from the Sediment Quality Triad (i.e., measures of chemical contamination, toxicity, and benthic community structure). The triad of measures was offered as an approach for developing a weight-of-evidence to classify the relative quality of sediments (Long, 1989). Chapman (1996) later suggested that locations with chemical concentrations greater than effects-based guidelines or criteria, and evidence of acute toxicity in laboratory tests (such as with the amphipod survival bioassays), and alterations to resident infaunal communities constituted “strong evidence of pollution-induced degradation”. In contrast, he suggested that there was “strong evidence against pollution-induced degradation” at sites lacking contamination, toxicity, and benthic alterations. Several other permutations were described in which mixed or conflicting results were obtained. In some cases, sediments could appear to be contaminated, but not toxic, either with or without alterations to the benthos, or sediments were not contaminated with measured substances, but, nevertheless, were toxic, either with or without benthic alterations. Plausible explanations were offered for benthic “alterations” at non-contaminated and/or non-toxic locations possibly attributable to natural factors, such as those identified above.

In this survey of central Puget Sound, 36 of the 100 stations sampled had sediments with significant toxicity and elevated chemical contamination, while 18 appeared to have benthic communities that were possibly affected by chemical contaminants in the sediments, including stations in Sinclair Inlet, Dyes Inlet, Elliott Bay, and the Duwamish River. These stations typically had moderate to very high total abundance, including high numbers of *Aphelochaeta* species N1 and other pollution-tolerant species, moderate to high taxa richness, low evenness, and low Swartz's Dominance Index values. Often, pollution-sensitive species such as arthropods and echinoderms were low in abundance or absent from these stations. These 18 stations represented an area of 8.1 km^2, or about 1.1% of the total survey area. These 18 stations, all located in urban/industrial areas, provide possible "evidence of pollution-induced degradation" as defined by Chapman, 1996.

In contrast, 25 stations were identified with no indications of significant sediment toxicity or chemical contamination. All of the benthic indices indicated abundant and diverse populations of most or all taxonomic groups. These stations, located in Port Townsend, Admiralty Inlet, Possession Sound, the central basin, Port Madison, Liberty Bay, the Bainbridge Basin, Rich Passage, Dyes Inlet, and outer Elliott Bay, represented an area of 359.3 km^2, equivalent to approximately 49% of the total survey area, and provide "strong evidence against pollution-induced degradation" as defined by Chapman, 1996.

The remaining thirty-nine stations, with either significant chemical contamination but no toxicity, or significant toxicity but no chemical contamination, were located in Port Townsend, Possession Sound, the central basin, Eagle Harbor, Liberty Bay, the Bainbridge Basin, and Elliott Bay and the Duwamish River, and represented an area of 272.6 km^2, equivalent to about 37% of the total central Puget Sound study area. Benthic assemblages varied considerably in structure at these stations, presumably as a result of many factors, including natural environmental variables. Additional statistical analyses are required to fully describe the multivariate relationships among the sediment quality triad data, and other variable data collected at all 100 stations.

Comparison of the results of the sediment quality triad analyses for this survey was made with the 1997 survey of northern Puget Sound (Table 40). In both surveys, the percent of the total study areas displaying toxicity, chemical contamination and altered benthos was similar (1.3 and 1.1% area, respectively). Of the area surveyed in 1997 (773.9 km^2), ten stations representing 10.34 km^2 (1.3% of the area) could be considered as having pollution-induced degradation. Nine of these samples were collected in Everett Harbor and one from Port Gardner. The estimate of 1.3% area was similar to the estimate of 1.1% for the 18 "degraded" stations identified in the central Puget Sound study area. In addition, 10.6% of the 1997 northern area had both high chemical contamination and high toxicity, but, was accompanied by high benthic abundance and diversity. For central Puget Sound, this estimate was similar (12.5%). In contrast, the samples with no contamination and no toxicity represented 19.6% of the northern area and 49% of the central area. Conversely, the balance of samples in which results were mixed (i.e., either chemistry or toxicity was significant, benthos was abundant and diverse) was almost twice as high in the northern study area (68.5%) than in the central study area (37%).

Because of the natural differences in benthic communities among different estuaries, it is difficult to compare the communities from Puget Sound with those from other regions in the U.S.

However, benthic data have been generated by the Estuaries component of the Environmental Monitoring and Assessment Program (EMAP) using internally consistent methods. A summary (Long, 2000) of the data from three estuarine provinces (Virginian, Louisianian, Carolinian) showed ranges in results for measures of species richness, total abundance, and a multi-parameter benthic index. The samples with relatively low species richness represented 5%, 4%, and 10% of the survey areas, respectively. Those with relatively low infaunal abundance represented 7%, 19%, and 22% of the areas, respectively. Samples with low benthic index scores represented 23%, 31%, and 20% of the areas. In the Regional EMAP survey of the New York/New Jersey harbor area, samples classified as having degraded benthos represented 53% of the survey area (Adams et al., 1998). In contrast, it appears that benthic conditions that might be considered degraded in central Puget Sound occurred much less frequently than in all of these other areas.

Conclusions

The conclusions drawn from the analysis of 100 sediment samples collected from central Puget Sound during June 1998 for toxicity, chemical concentrations, and benthic infaunal composition study, included the following:

- A battery of laboratory toxicity tests, used to provide a comprehensive assessment of the toxicological condition of the sediments, indicated overlapping, but different, patterns in toxicity. Several spatial patterns identified with results of all the tests were apparent in this survey. First, highly toxic responses in the sea urchin, Microtox™, and cytochrome P450 HRGS tests were observed in the inner strata of Elliott Bay and the lower Duwamish River. Toxicity in these tests decreased considerably westward into the outer and deeper regions of the bay. Second, many of the samples from the Liberty Bay and Bainbridge basin area were toxic in the Microtox™ and cytochrome P450 HRGS assays. The degree of toxicity decreased steadily southward down the Bainbridge basin to Rich Passage, where the sediments were among the least toxic. Third, samples from two stations (167 and 168) located in a small inlet off Port Washington Narrows were among the most toxic in two or more tests. Fourth, several samples from stations scattered within Sinclair Inlet indicated moderately toxic conditions; toxicity diminished steadily eastward into Rich Passage. Finally, samples from Port Townsend, southern Admiralty Inlet, and much of the central main basin were among the least toxic.

- The spatial extent of toxicity was estimated by weighting the results of each test to the sizes of the sampling strata. The total study area was estimated to represent about 732 kilometer^2. The area in which highly significant toxicity occurred totaled approximately 0.1% of the total area in the amphipod survival tests; 0.7%, 0.2%, and 0.6% of the area in urchin fertilization tests of 100%, 50%, and 25% pore waters, respectively; 0% of the area in microbial bioluminescence tests; and 3% of the area in the cytochrome P450 HRGS assays. The estimates of the spatial extent of toxicity measured in three of the four tests in central Puget Sound were considerably lower than the "national average" estimates compiled from many other surveys previously conducted by NOAA. Generally, they were comparable to the estimates for northern Puget Sound. However, in the cytochrome P450 HRGS assays, a relatively high proportion of samples caused moderate responses. Overall, the data from these four tests suggest that central Puget Sound sediments were not as toxic relative to sediments from many other areas nationwide. The large majority of the area surveyed was classified as non-toxic in these tests. However, the data from the RGS assays indicated a slight to moderate response among many samples.

- Chemical analyses, performed for a wide variety of trace metals, aromotic hydrocarbons, chlorinated organic hydrocarbons, and other ancillary measures, indicated that the surficial area in which chemical concentrations exceeded effects-based sediment guidelines was highly dependent upon the set of critical values that was used. There were 21 samples in which one or more ERM values were exceeded. They represented an area of about 21 km^2, or about 3% of the total survey area. In contrast, there were 94 samples in which at least one SQS or CSL value was exceeded, representing about 99% of the survey area. Without the data for benzoic acid, 44 samples had at least one chemical concentration greater than a SQS (25.2% of the area) and 36 samples had at least one concentration greater than a CSL (21% of the area).

- The highest chemical concentrations invariably were observed in samples collected in the urbanized bays, namely Elliott Bay and Sinclair Inlet. Often, these samples contained chemicals at concentrations previously observed to be associated with acute toxicity and other biological effects. Concentrations generally decreased steadily away from these two bays and were lowest in Admiralty Inlet, Possession Sound, Rich Passage, Bainbridge Basin, and most of the central basin.

- Toxicity tests performed for urchin fertilization, microbial bioluminescence, and cytochrome P450 HRGS enzyme induction indicated correspondence with complex mixtures of potentially toxic chemicals in the sediments. Often, the results of the urchin and cytochrome P450 HRGS tests showed the strongest correlations with chemical concentrations. As expected, given the nature of the tests, results of the cytochrome P450 HRGS assay were highly correlated with concentrations of high molecular weight PAHs and other organic compounds known to induce this enzymatic response. In some cases, samples that were highly toxic in the urchin or cytochrome P450 HRGS tests had chemical concentrations that exceeded numerical, effects-based, sediment quality guidelines, further suggesting that these chemicals could have caused or contributed to the observed biological response. However, there was significant variability in some of the apparent correlations, including samples in which chemical concentrations were elevated and no toxicity was observed. Therefore, it is most likely that the chemical mixtures causing toxicity differed among the different toxicity tests and among the regions of the survey area.

- Several indices of the relative abundance and diversity of the benthic infauna indicated very wide ranges in results among sampling stations. Often, the samples collected in portions of the central basin, Port Townsend Bay, Rich Passage, and outer reaches of Elliott Bay had the highest abundance and diversity of infauna. Often, annelids dominated the infauna, especially in samples with unusually high total abundance. Arthropods often were low in abundance in samples with low overall abundance and diversity. Samples in which the indices of abundance and diversity were lowest were collected in the lower Duwamish River, inner Elliott Bay, and Sinclair Inlet.

- Statistical analyses of the toxicity data and benthic data revealed few consistent patterns. Some indices of benthic community diversity and abundance decreased with increasing toxicity and others increased. Also, the relationships between measures of benthic structure and chemical concentrations showed mixed results. Total abundance and annelid abundance often increased significantly in association with increasing chemical concentrations. In contrast, indices of evenness, dominance, diversity, and abundance of several of the major taxonomic groups decreased with increasing concentrations of most individual chemicals and chemical classes. No single chemical or chemical class was uniquely correlated with the measures of benthic structure.

- Data from the chemical analyses, toxicity tests, and benthic community analyses, together, indicated that of the 100 stations sampled, 36 had sediments with significant toxicity and elevated chemical contamination. Of these, 18 appeared to have benthic communities that were possibly affected by chemical contaminants in the sediments. They included stations in Sinclair Inlet, Dyes Inlet, Elliott Bay and the Duwamish River. These stations typically had moderate to very high total abundance, including high numbers of *Aphelochaeta* species N1 and other pollution-tolerant species, moderate to high taxa richness, low evenness, and low Swartz's Dominance Index values. Often, pollution-sensitive species such as arthropods and echinoderms were low in abundance or absent from these stations. These 18 stations represented an area of 8.1 km^2, or about 1.1% of the total survey area, while the remaining other 18 stations represented an area of 91.6 km^2, or about 12.5% of the total survey area. Twenty-five stations located in Port Townsend, Admiralty Inlet, Possession Sound, the central basin, Port Madison, Liberty Bay, the Bainbridge Basin, Rich Passage, Dyes Inlet, and outer Elliott Bay, were identified with no indications of significant sediment toxicity or chemical contamination, and with abundant and diverse populations of benthic infauna. These stations represented an area of 359.31 km^2, equivalent to 49% of the total survey area. The remaining thirty-nine stations, located in Port Townsend, Possession Sound, the central basin, Eagle Harbor, Liberty Bay, the Bainbridge Basin, and Elliott Bay and the Duwamish River, displayed either signs of significant chemical contamination but no toxicity, or significant toxicity, but no chemical contamination, and for the majority, the benthic populations were abundant and diverse. Together, these stations represented an area of 272.6 km^2, equivalent to 37% of the total central Puget Sound study area.

- A comparison of the "triad" results from both the northern and central Puget Sound study areas showed some similarities and some differences. Although the spatial extent of toxicity in the urchin fertilization tests and microbial bioluminescence tests was greater in the northern area, the cytochrome P450 HRGS tests indicated degraded conditions were more widespread in the central area. In both surveys, the percent of the total study areas displaying toxicity, chemical contamination and altered benthos was similar (1.3 and 1.1% area, respectively). Of the area surveyed in 1997 (773.9 km^2), ten stations representing 10.34 km^2 (1.3% of the area) could be considered as having pollution-induced degradation. The estimate of 1.3% area was similar to the estimate of 1.1% for the 18 "degraded" stations identified in the central Puget Sound study area. In addition, 10.6% of the 1997 northern area had both high chemical contamination and high toxicity, but, was accompanied by high benthic abundance and diversity. For central Puget Sound, this estimate was similar (12.5%). In contrast, the samples with no contamination and no toxicity represented 19.6% of the northern area and 49% of the central area. Conversely, the balance of samples in which results were mixed (i.e., either chemistry or toxicity was significant, benthos was abundant and diverse) was almost twice as high in the northern study area (68.5%) than in the central study area (37%).

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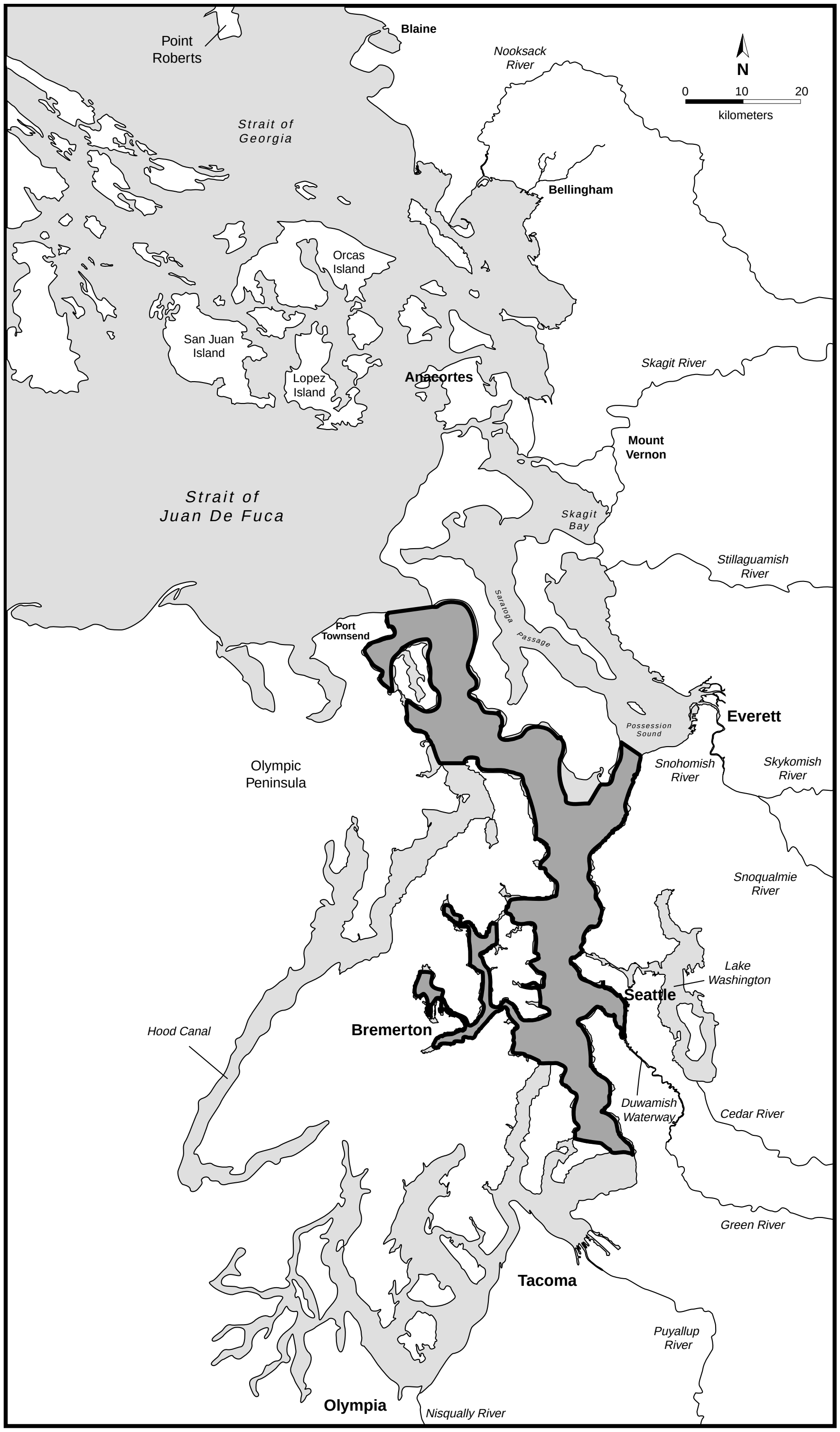


Figure 1. Map of the central Puget Sound study area for the NOAA/PSAMP Cooperative Agreement. The areas sampled during 1998 are outlined.

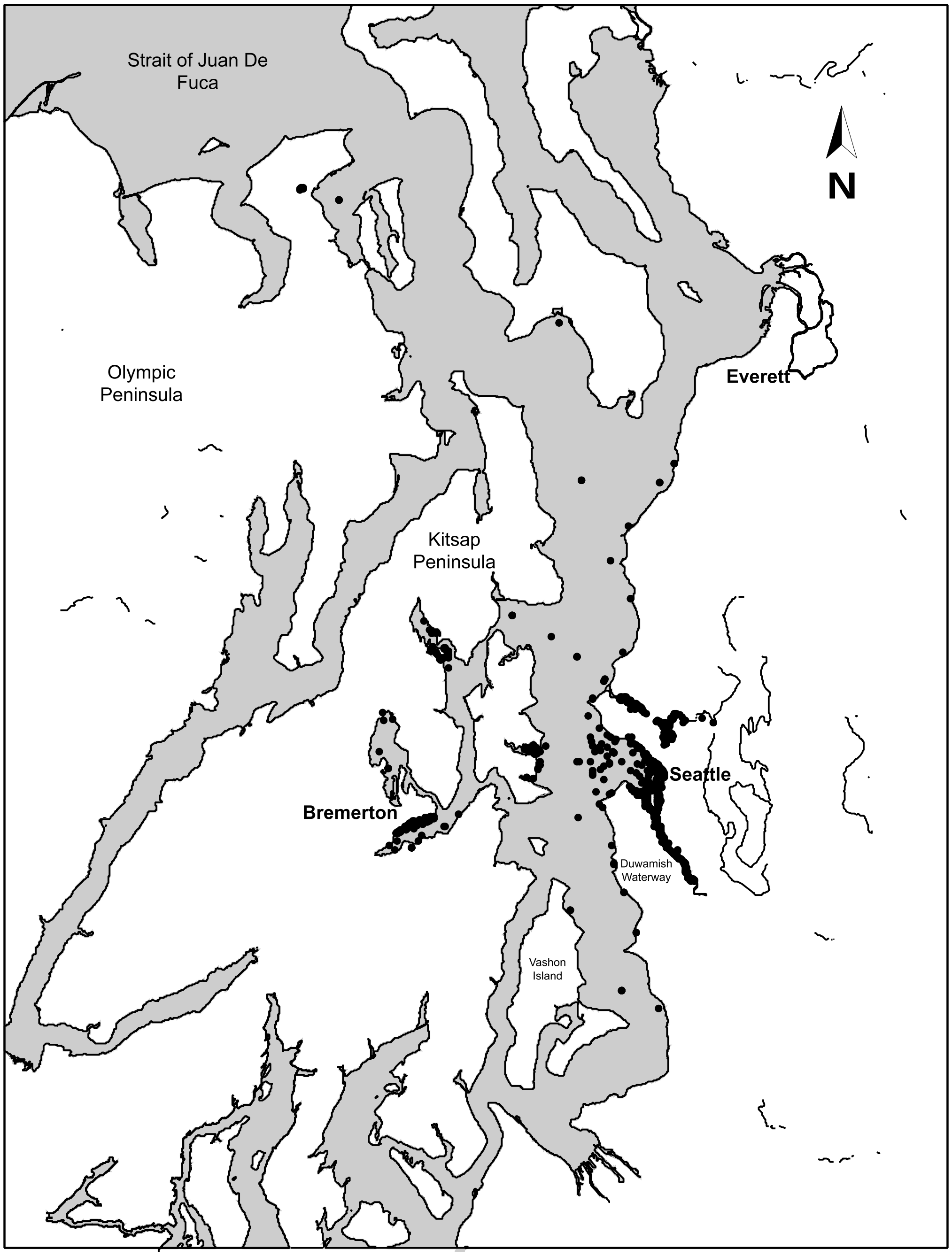


Figure 2. Map of central Puget Sound SEDQUAL stations where chemical contaminants in sediment samples exceeded Washington State Sediment Quality Standards (SQS) and Puget Sound Marine Sediment Cleanup Screening Levels (CSL).

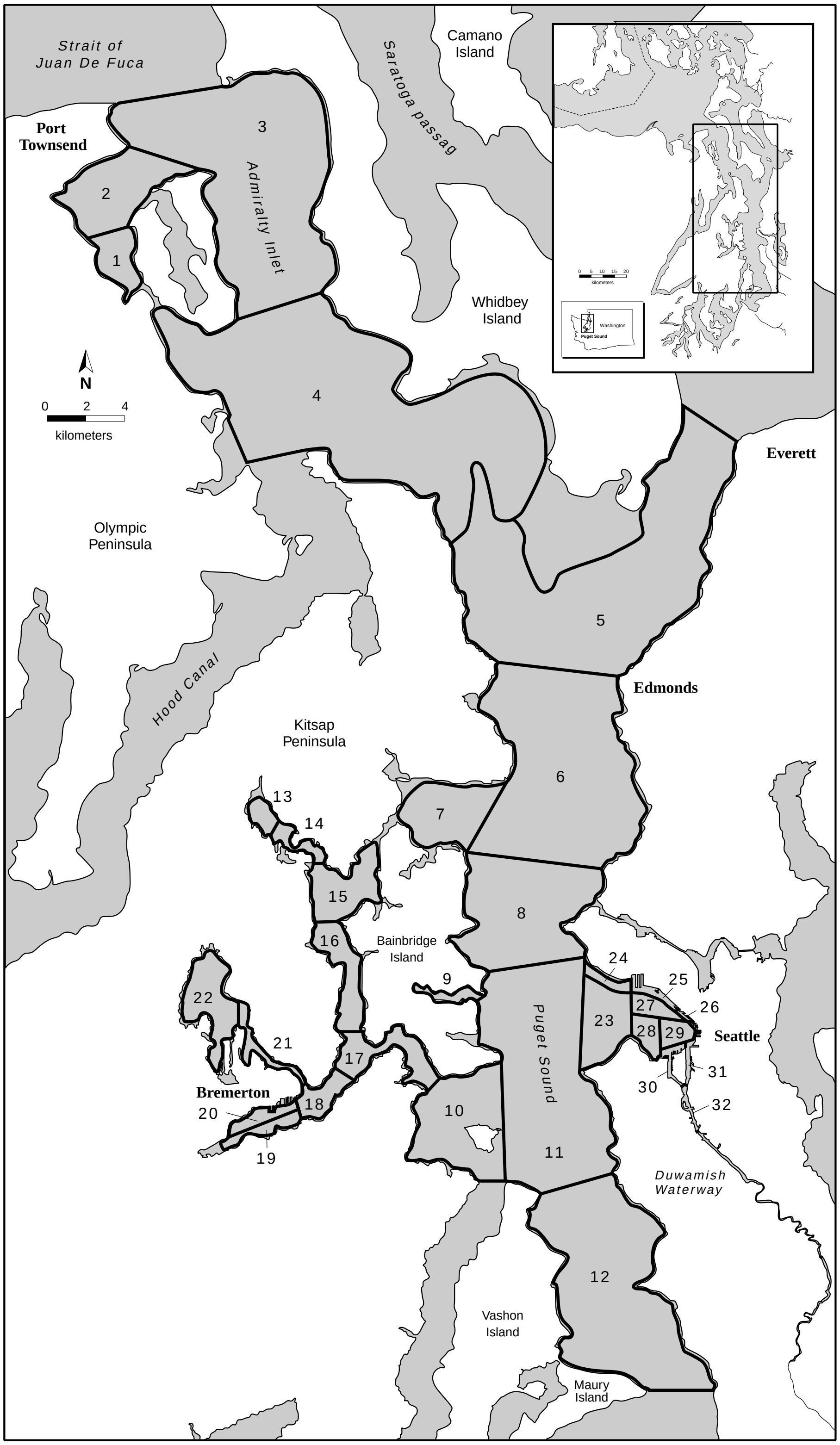


Figure 3a. Central Puget Sound sampling strata for the PSAMP/NOAA Bioeffects Survey, all strata.

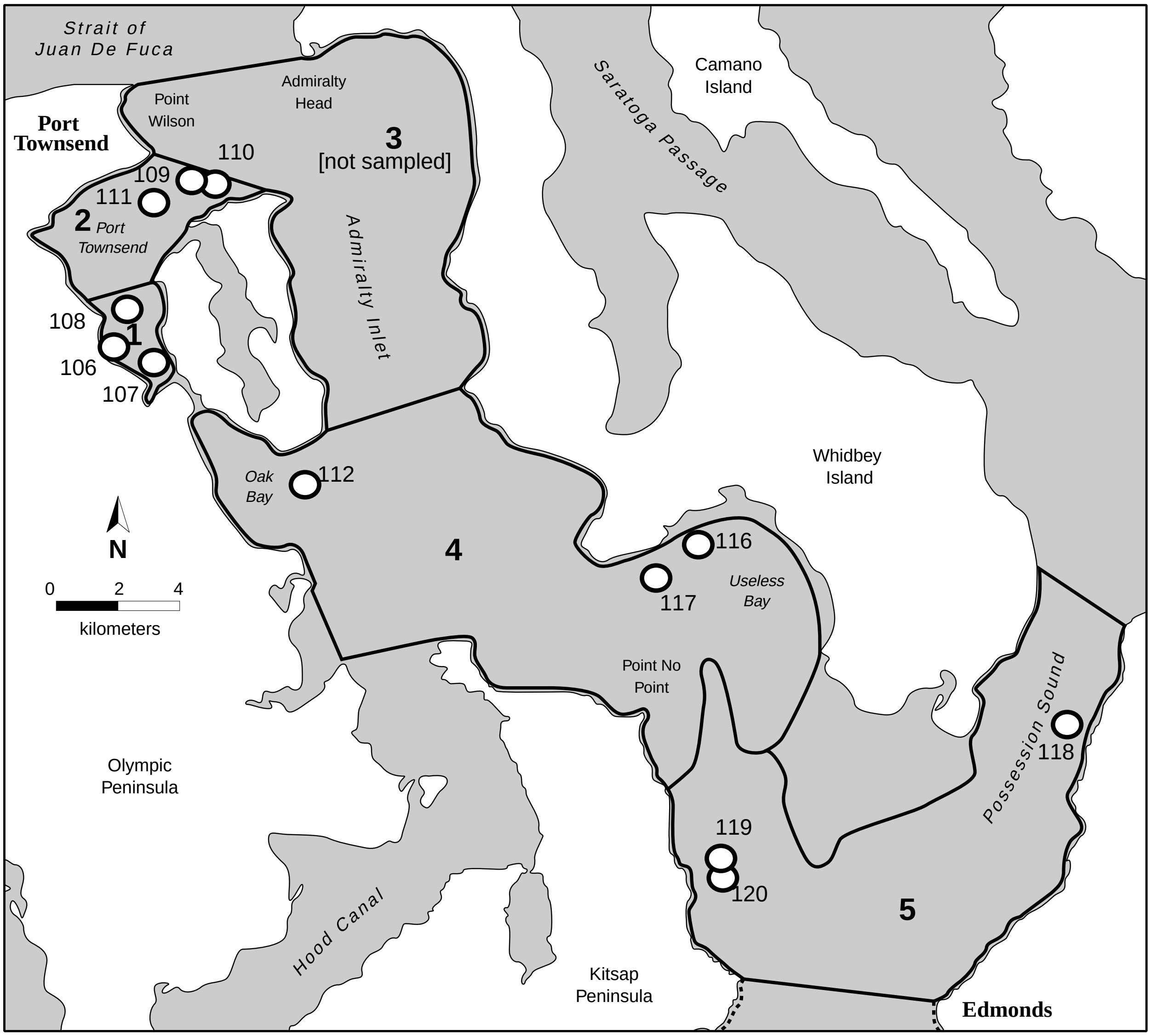


Figure 3b. Central Puget Sound sampling stations for the 1998 PSAMP/NOAA Bioeffects Survey, Port Townsend to Possession Sound (strata 1 through 5). (Strata numbers are shown in bold. Stations are identified as sample number).

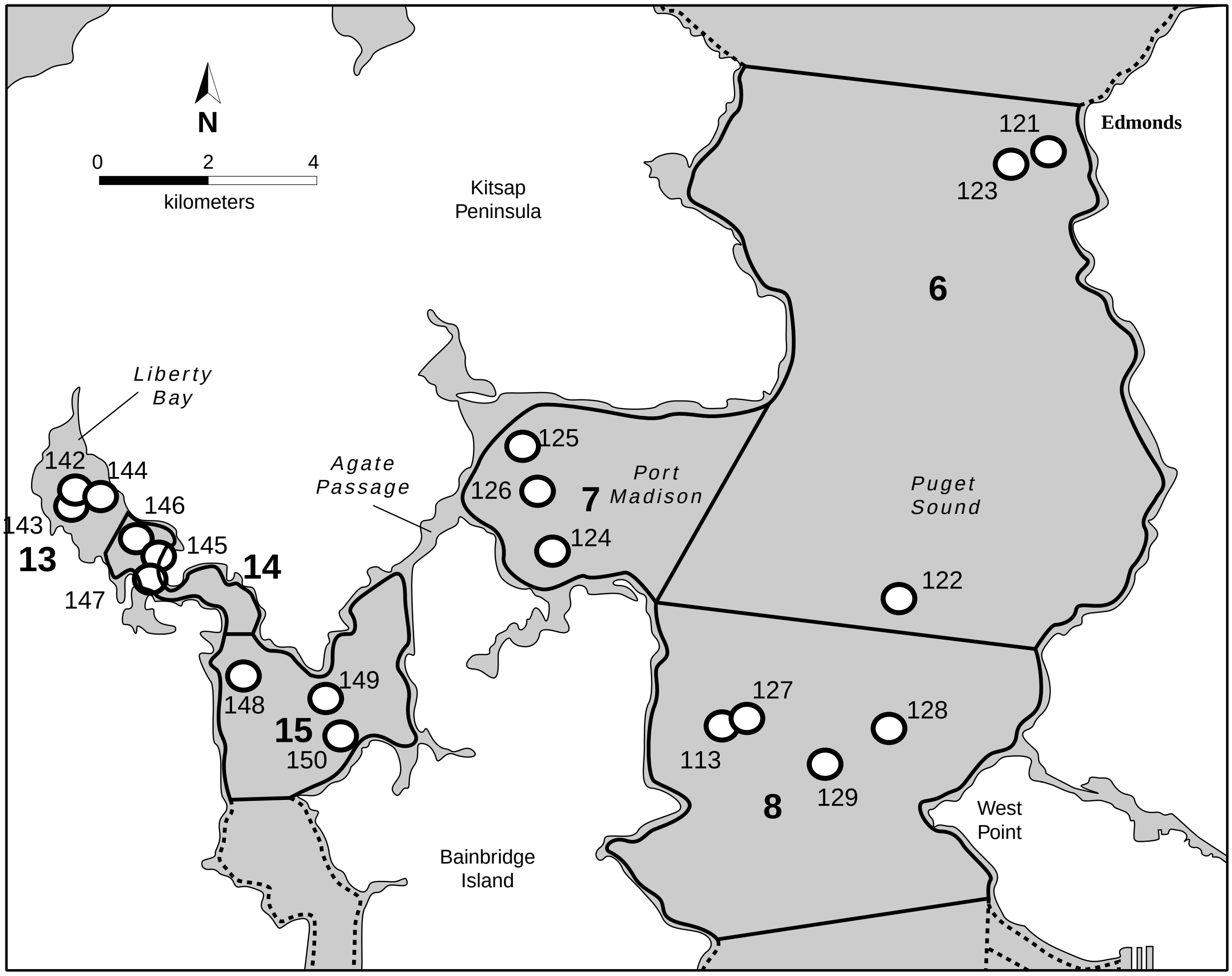


Figure 3c. Central Puget Sound sampling stations for the 1998 PSAMP/NOAA Bioeffects Survey, Port Madison and central basin (strata 6 through 8) and Liberty Bay to Bainbridge Island (13 through 15). (Strata numbers are shown in bold. Stations are identified as sample number).

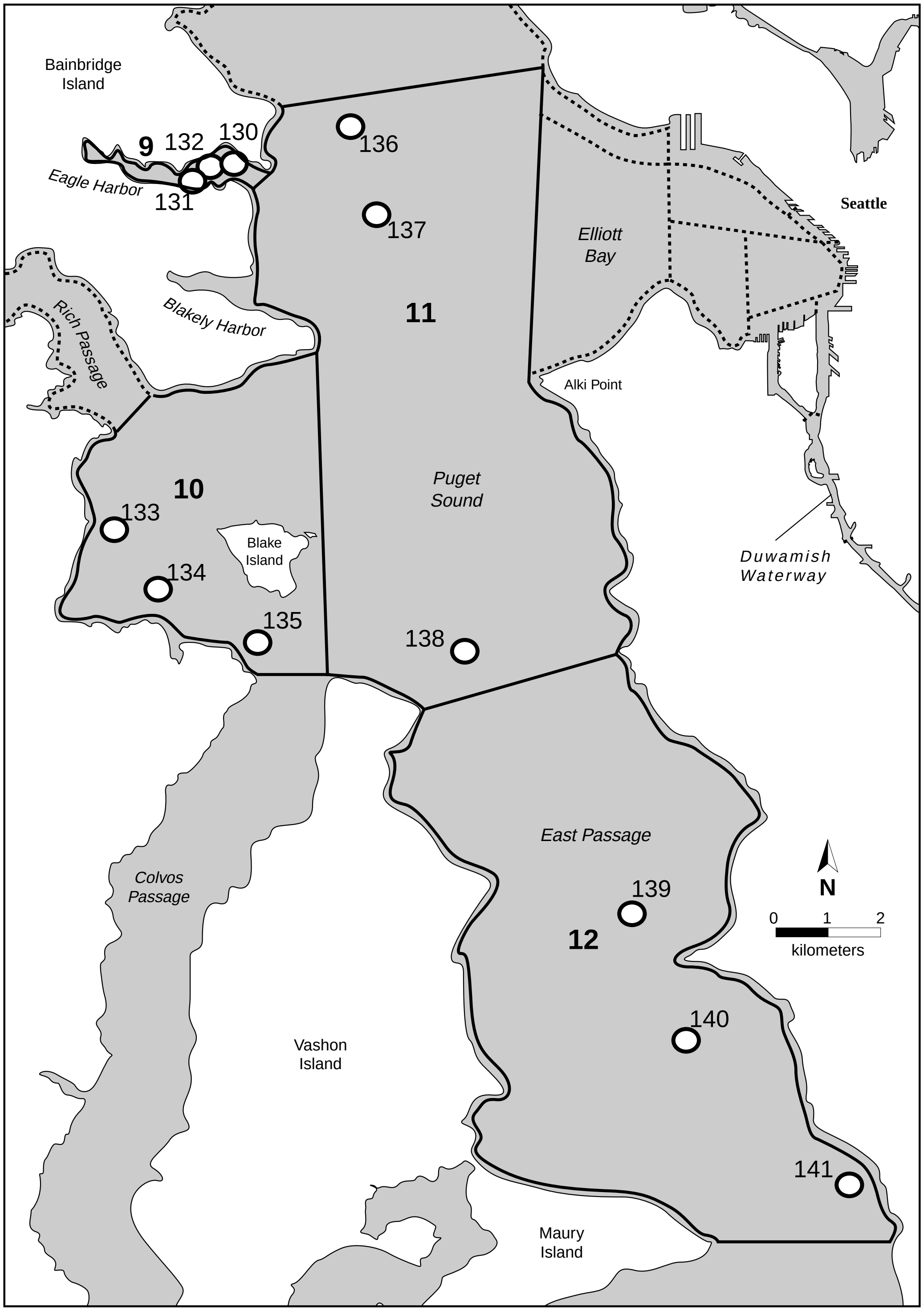


Figure 3d. Central Puget Sound sampling stations for the 1998 PSAMP/NOAA Bioeffects Survey, Eagle Harbor, central basin, and East Passage, (strata 9 through 12). (Strata numbers are shown in bold. Stations are identified as sample number).

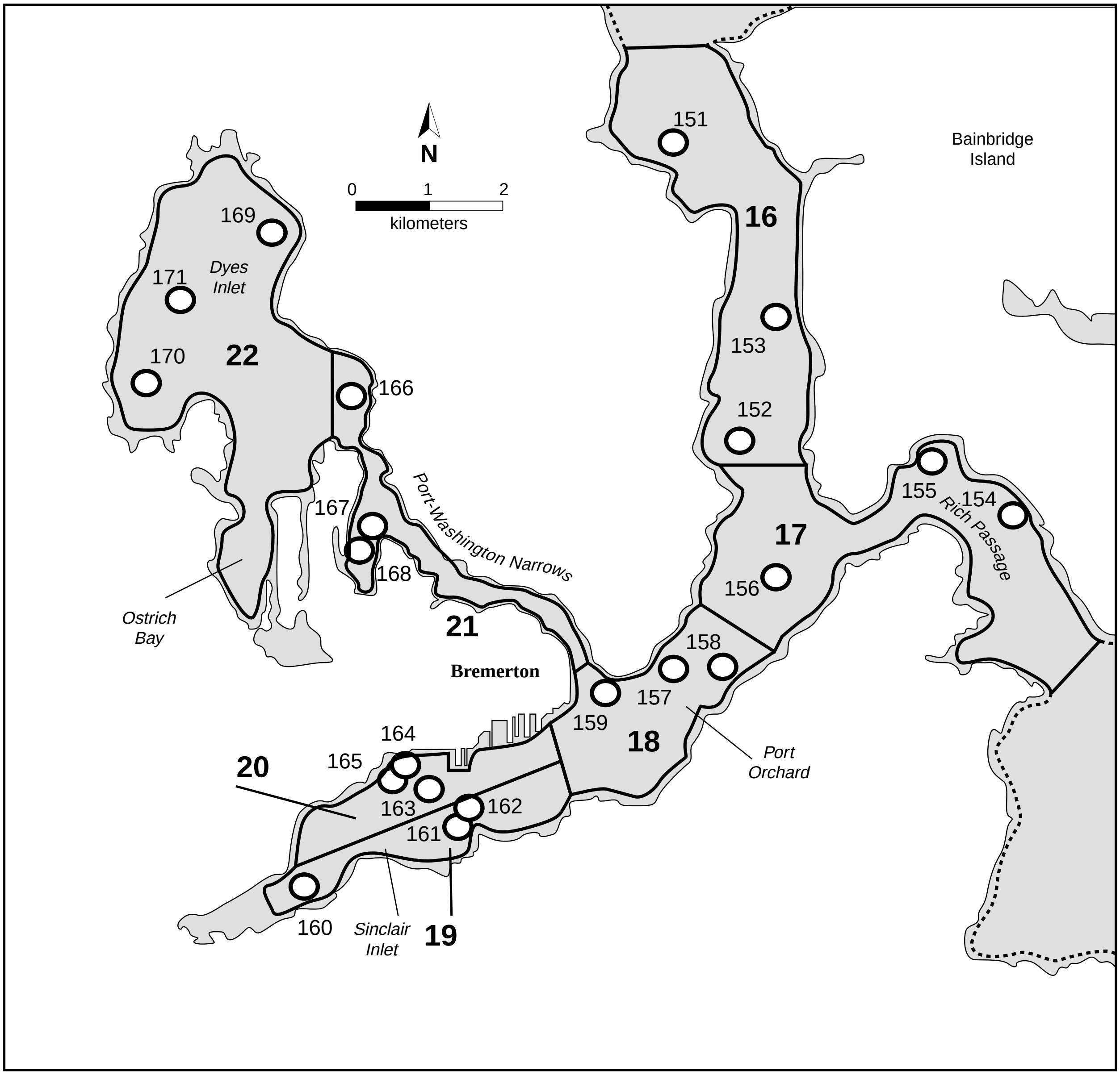


Figure 3e. Central Puget Sound sampling stations for the 1998 PSAMP/NOAA Bioeffects Survey, Bremerton to Port Orchard (strata 16 through 22). (Strata numbers are shown in bold. Stations are identified as sample number).

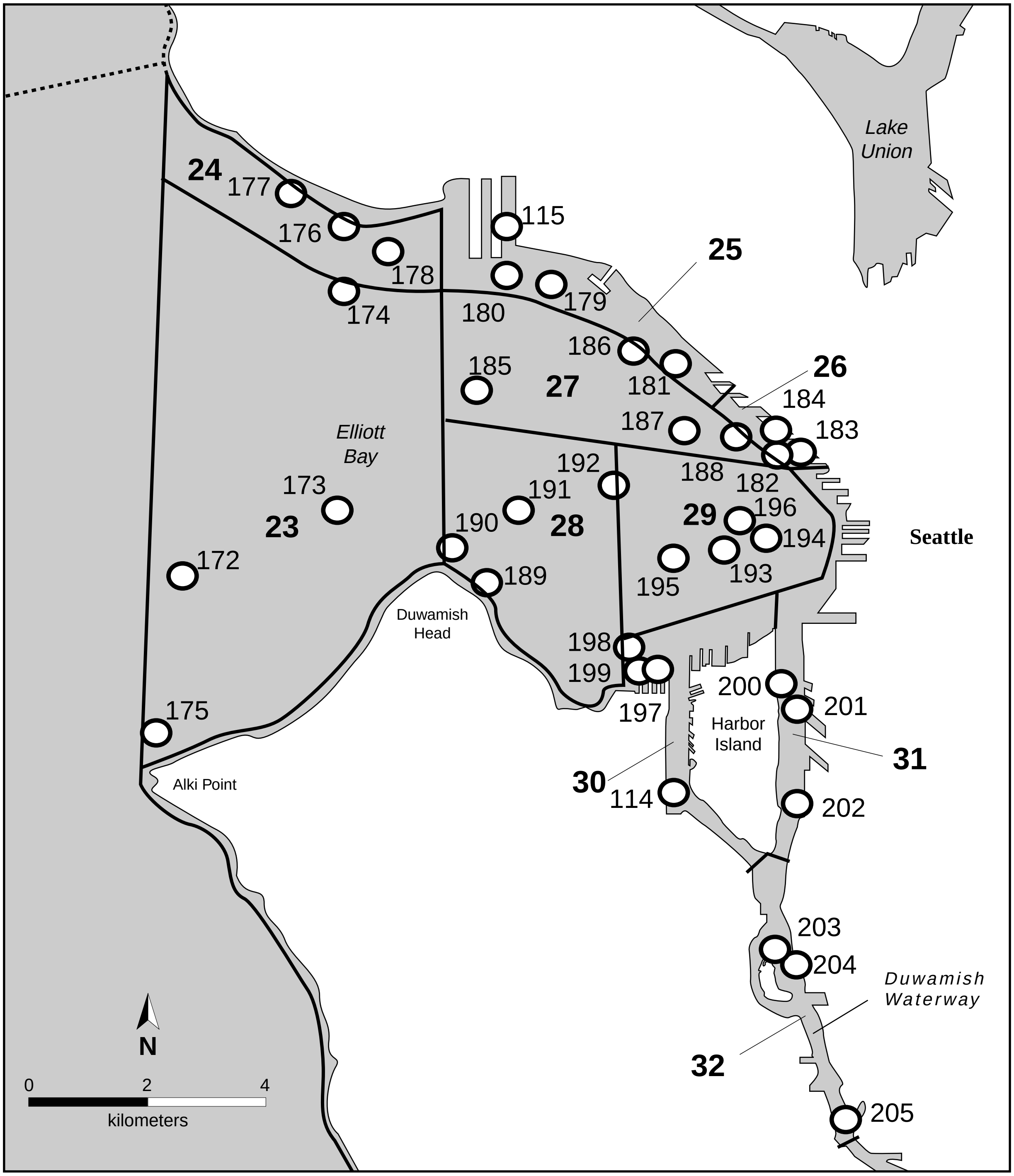


Figure 3f. Central Puget Sound sampling stations for the 1998 PSAMP/NOAA Bioeffects Survey, Elliott Bay and the lower Duwamish River (strata 23 through 32). (Strata numbers are shown in bold. Stations are identified as sample number).

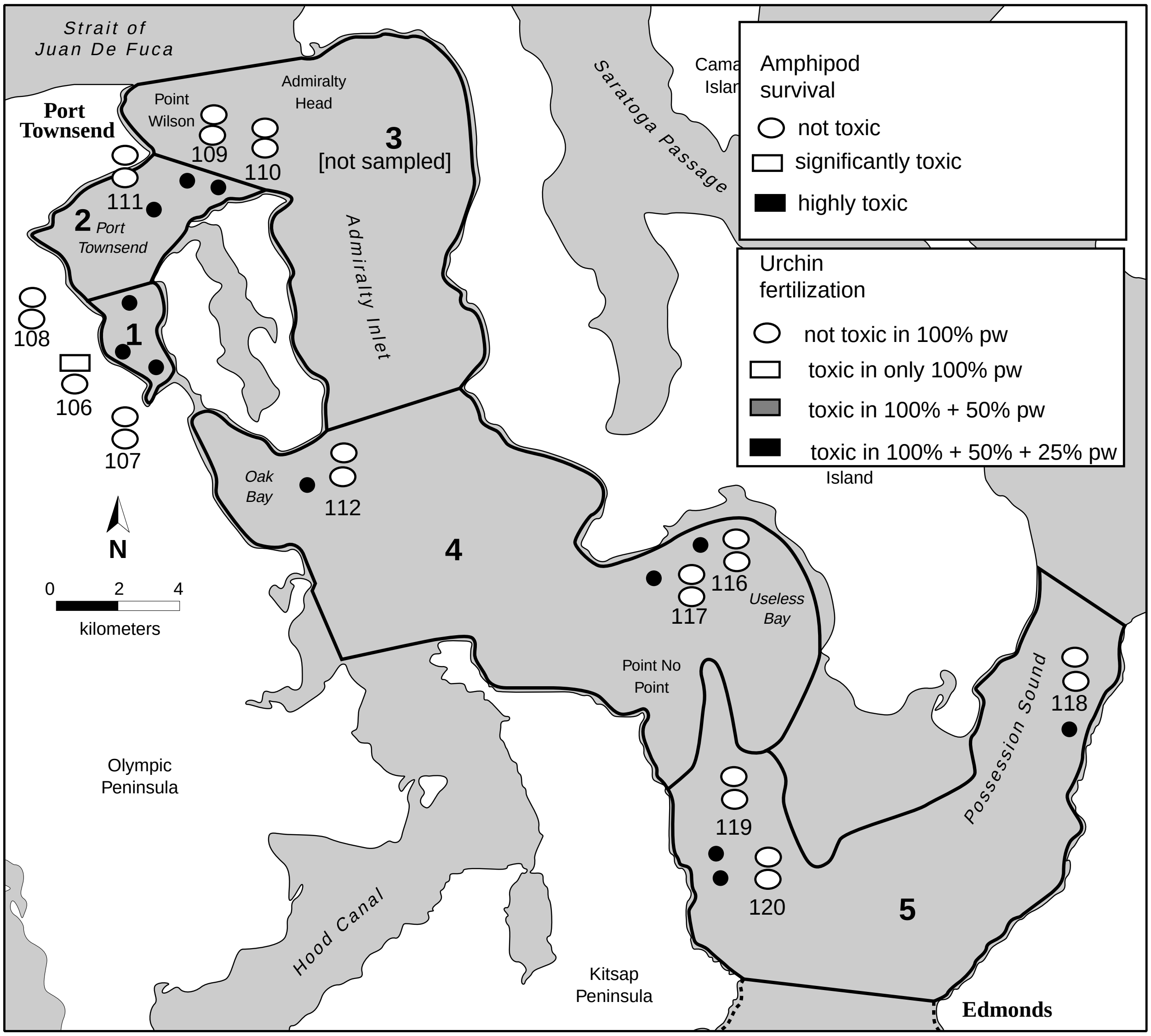


Figure 4. Summary of 1998 amphipod survival tests (top symbols) and sea urchin fertilization tests (in three porewater concentrations, bottom symbols) for stations in Port Townsend to Possession Sound (strata 1 through 5). (Strata numbers are shown in bold. Stations are identified as sample number).

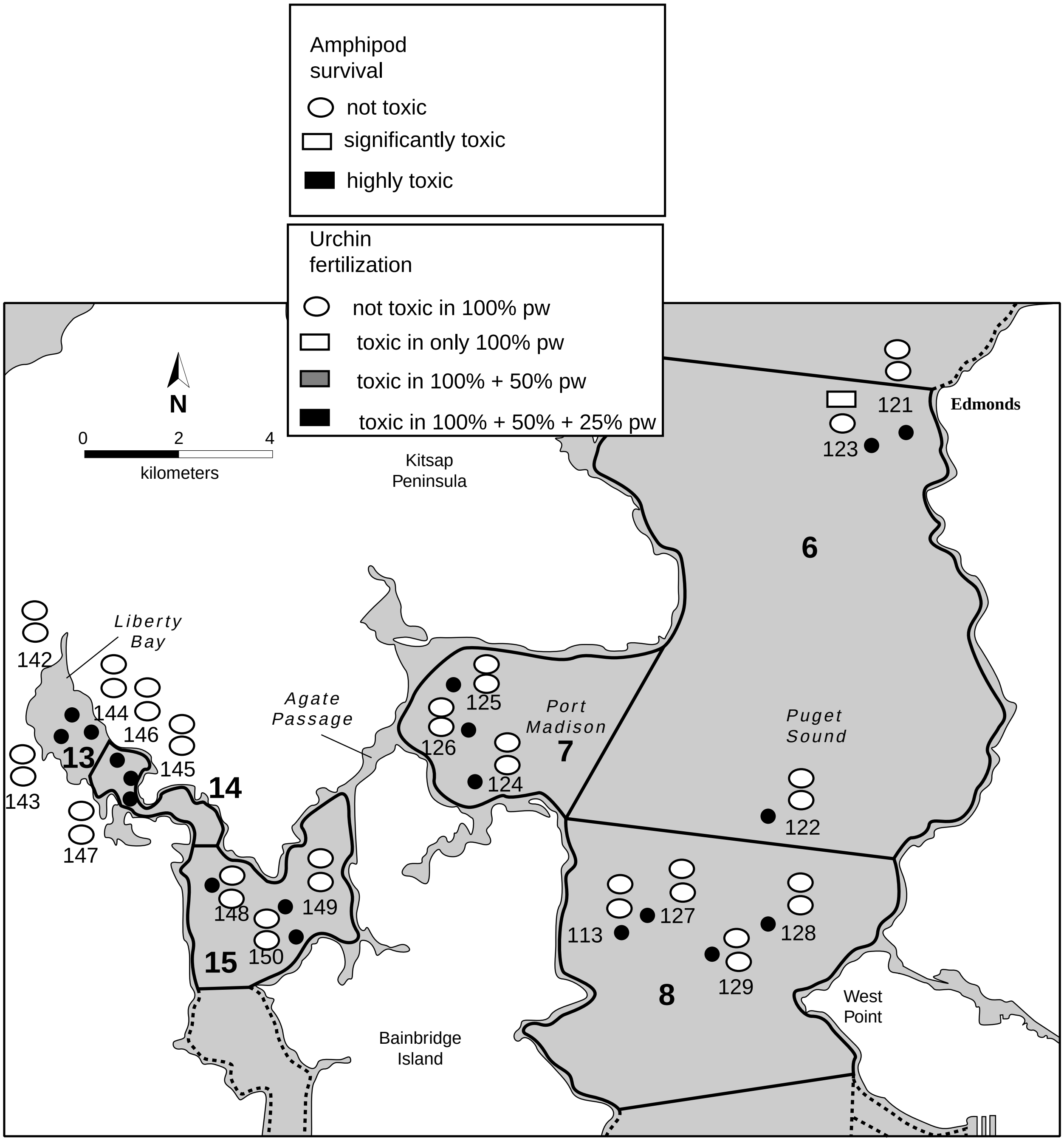


Figure 5. Summary of 1998 amphipod survival tests (top symbols) and sea urchin fertilization tests (in three porewater concentrations, bottom symbols) for stations in Port Madison and central basin (strata 6 through 8) and Liberty Bay to Bainbridge Island (13 through 15). (Strata numbers are shown in bold. Stations are identified as sample number).

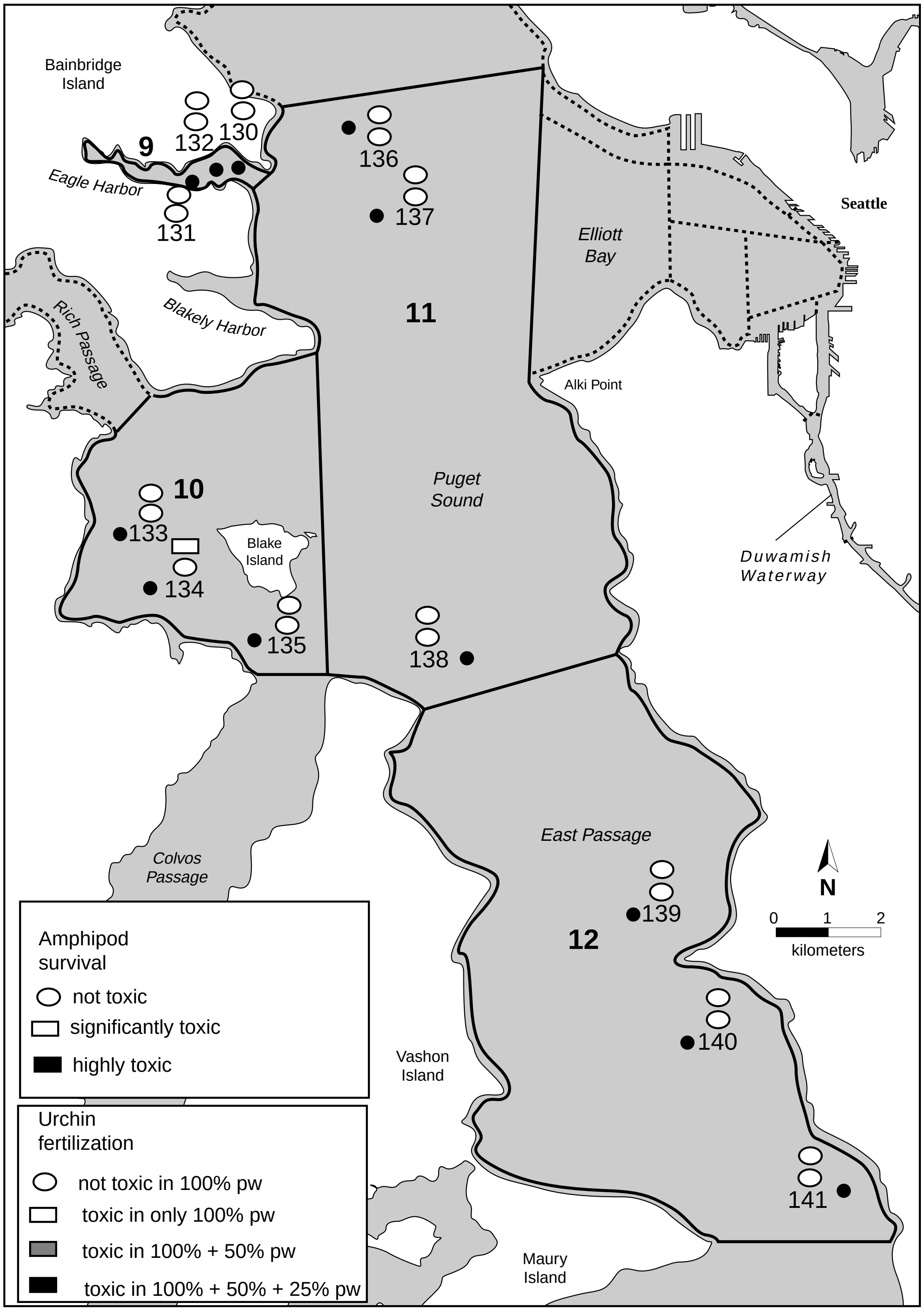


Figure 6. Summary of 1998 amphipod survival tests (top symbols) and sea urchin fertilization tests (in three porewater concentrations, bottom symbols) for stations in Eagle Harbor, central basin, and East Passage (strata 9 through 12). (Strata numbers are shown in bold. Stations are identified as sample number)

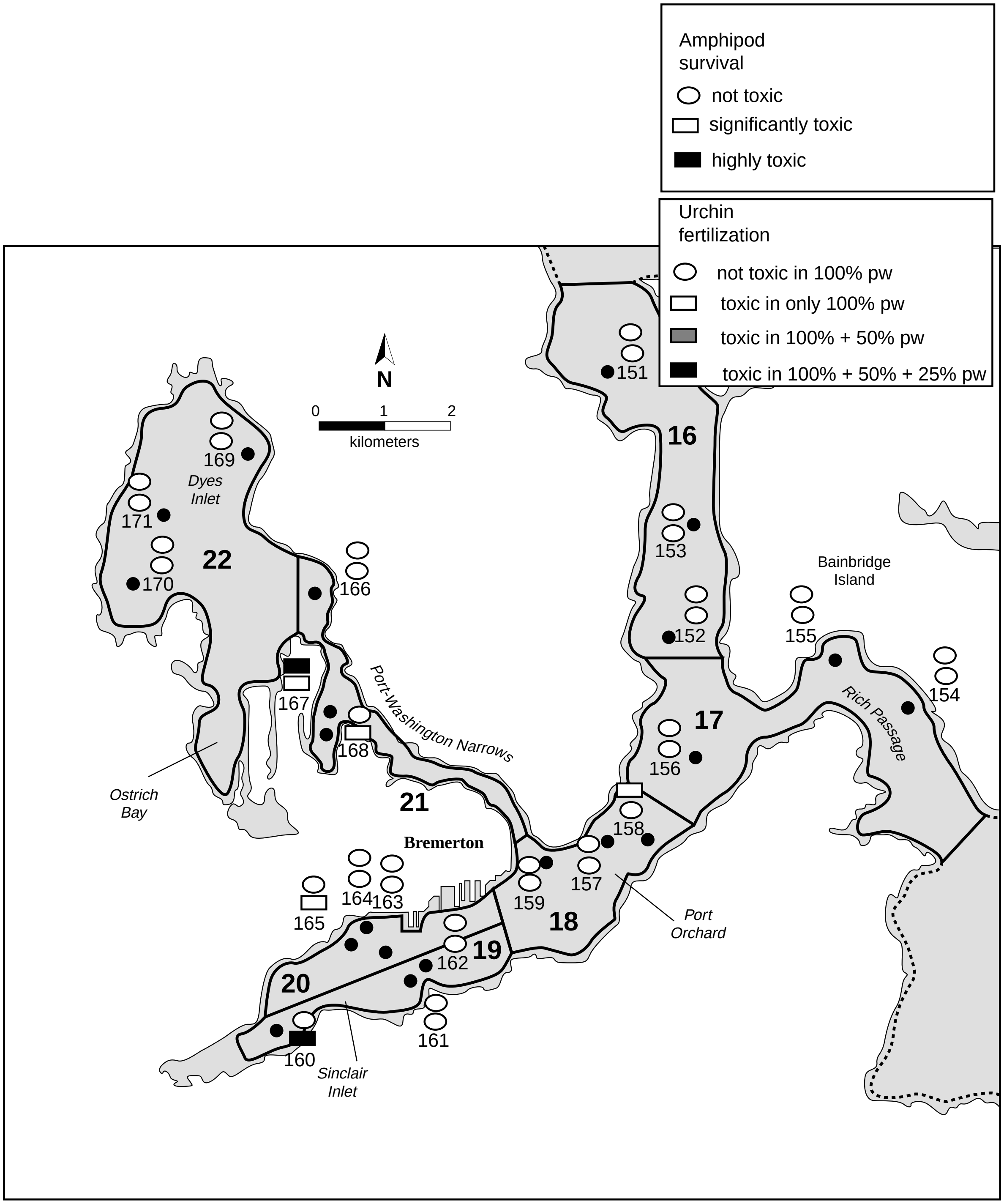


Figure 7. Summary of 1998 amphipod survival tests (top symbols) and sea urchin fertilization tests (in three porewater concentrations, bottom symbols) for stations in Bremerton to Port Orchard (strata 16 through 22). (Strata numbers are shown in bold. Stations are identified as sample number).

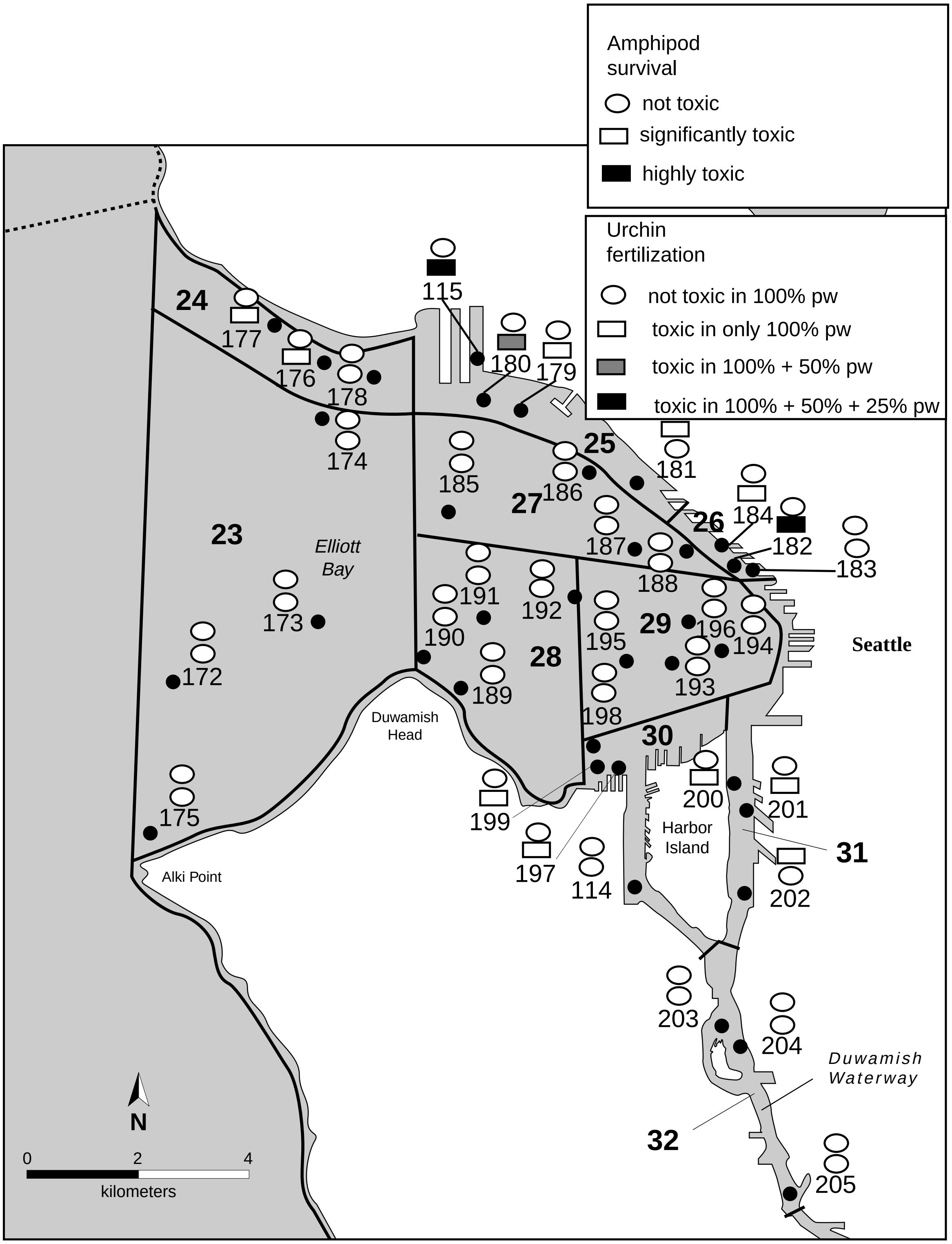


Figure 8. Summary of 1998 amphipod survival tests (top symbols) and sea urchin fertilization tests (in three porewater concentrations, bottom symbols) for stations in Elliott Bay and the lower Duwamish River (strata 23 through 32). (Strata numbers are shown in bold. Stations are identified as sample number).

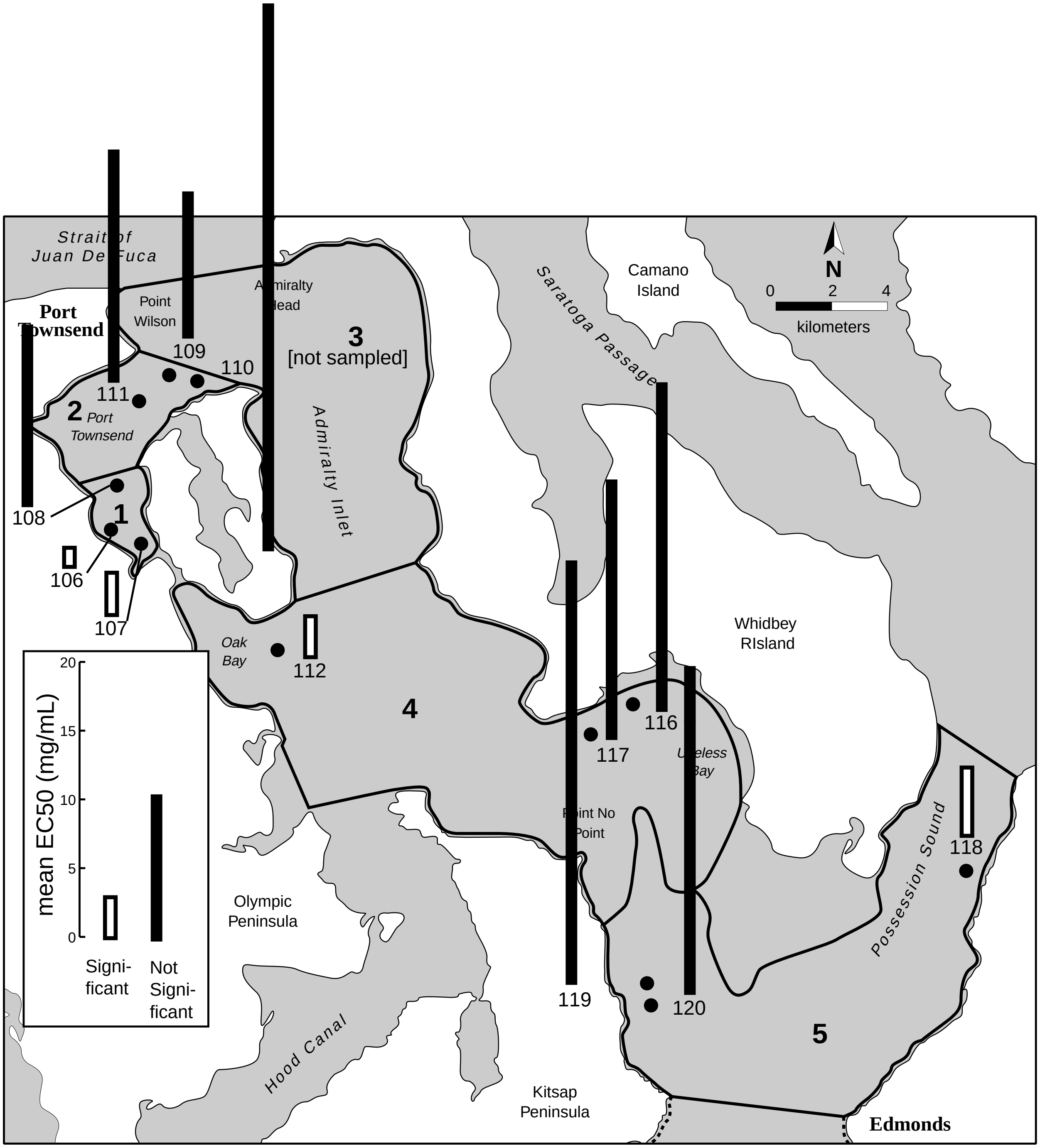


Figure 9. Results of 1998 Microtox™ bioluminescence tests for stations in Port Townsend to Possession Sound (strata 1 through 5). (Strata numbers are shown in bold. Stations are identified as sample number).

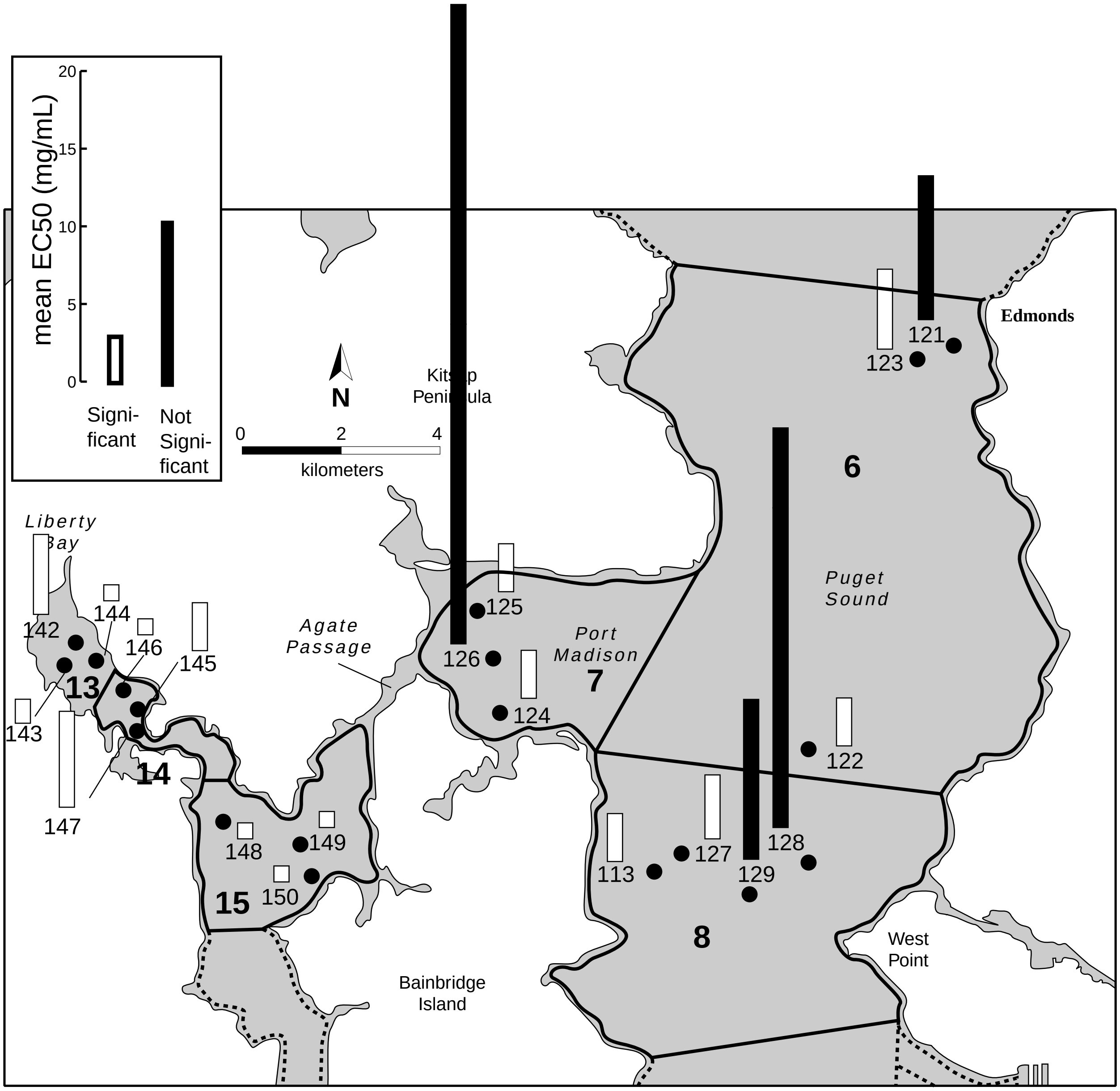


Figure 10. Results of 1998 Microtox™ bioluminescence tests for stations in Port Madison and central basin (strata 6 through 8) and Liberty Bay to Bainbridge Island (13 through 15). (Strata numbers are shown in bold. Stations are identified as sample number).

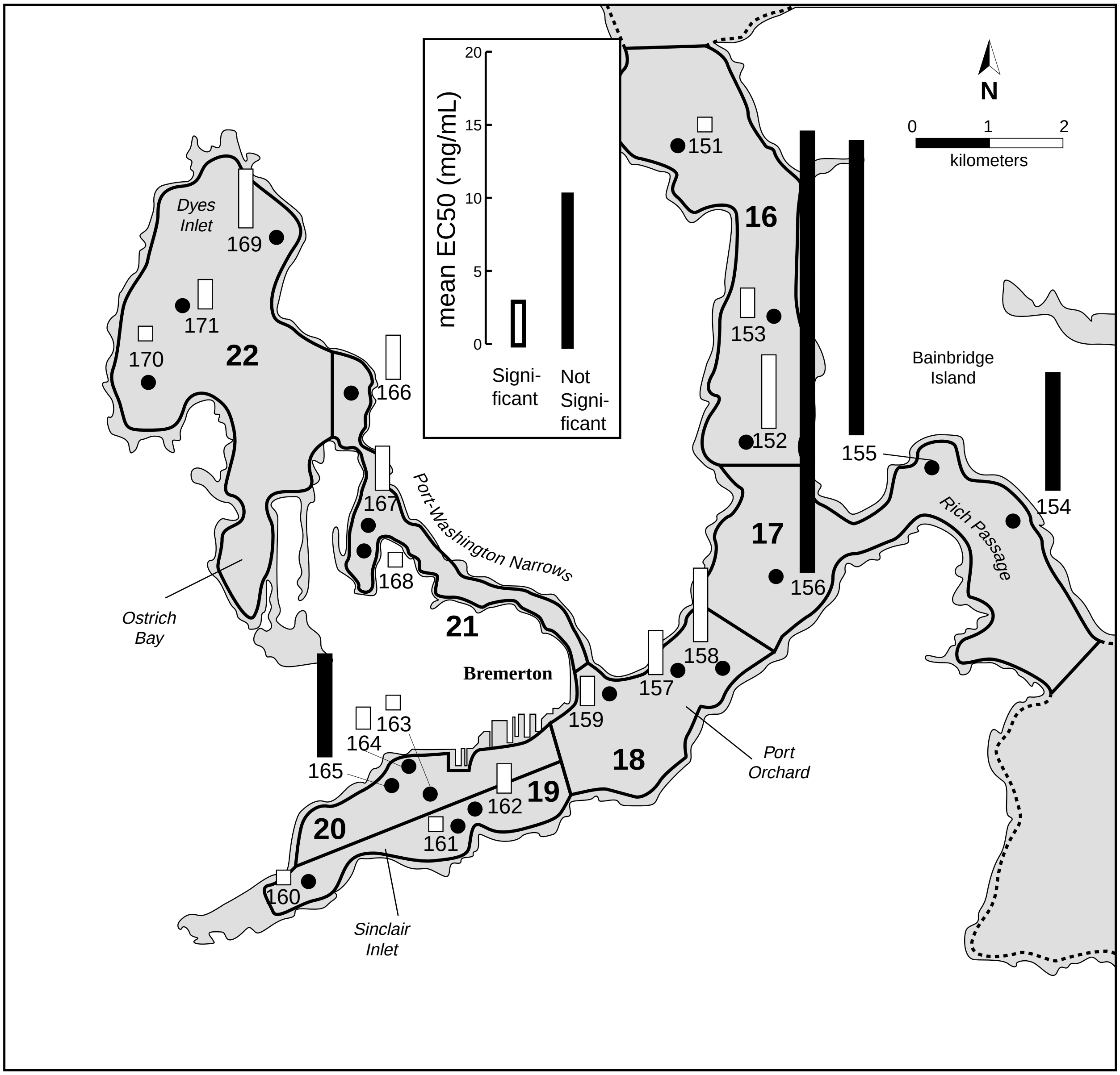


Figure 11. Results of 1998 Microtox™ bioluminescence tests for stations in Bremerton to Port Orchard (strata 16 through 22). (Strata numbers are shown in bold. Stations are identified as sample number).

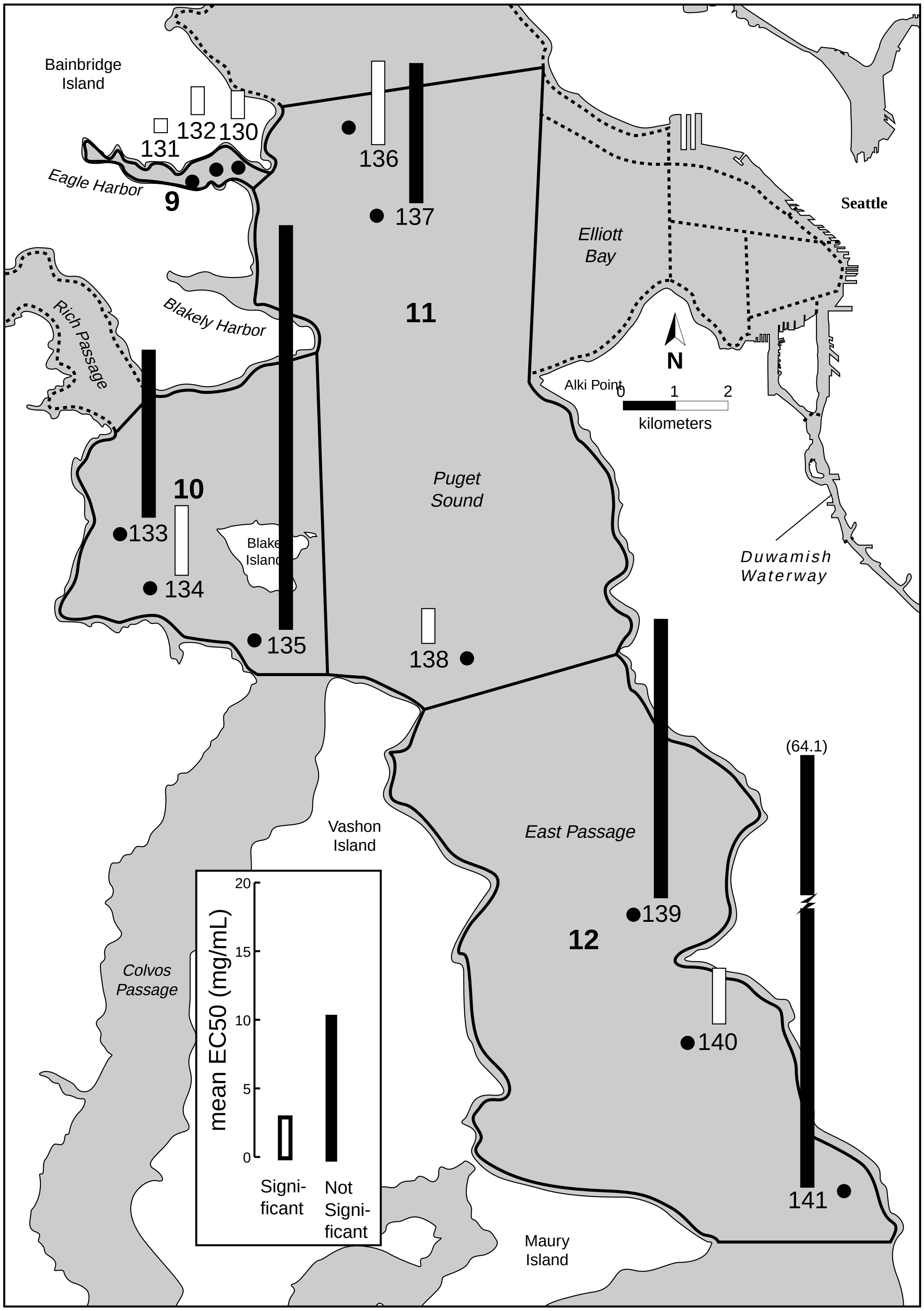


Figure 12. Results of 1998 Microtox™ bioluminescence for stations in Eagle Harbor, central basin, and East Passage (strata 9 through 12). (Strata numbers are shown in bold. Stations are identified as sample number).

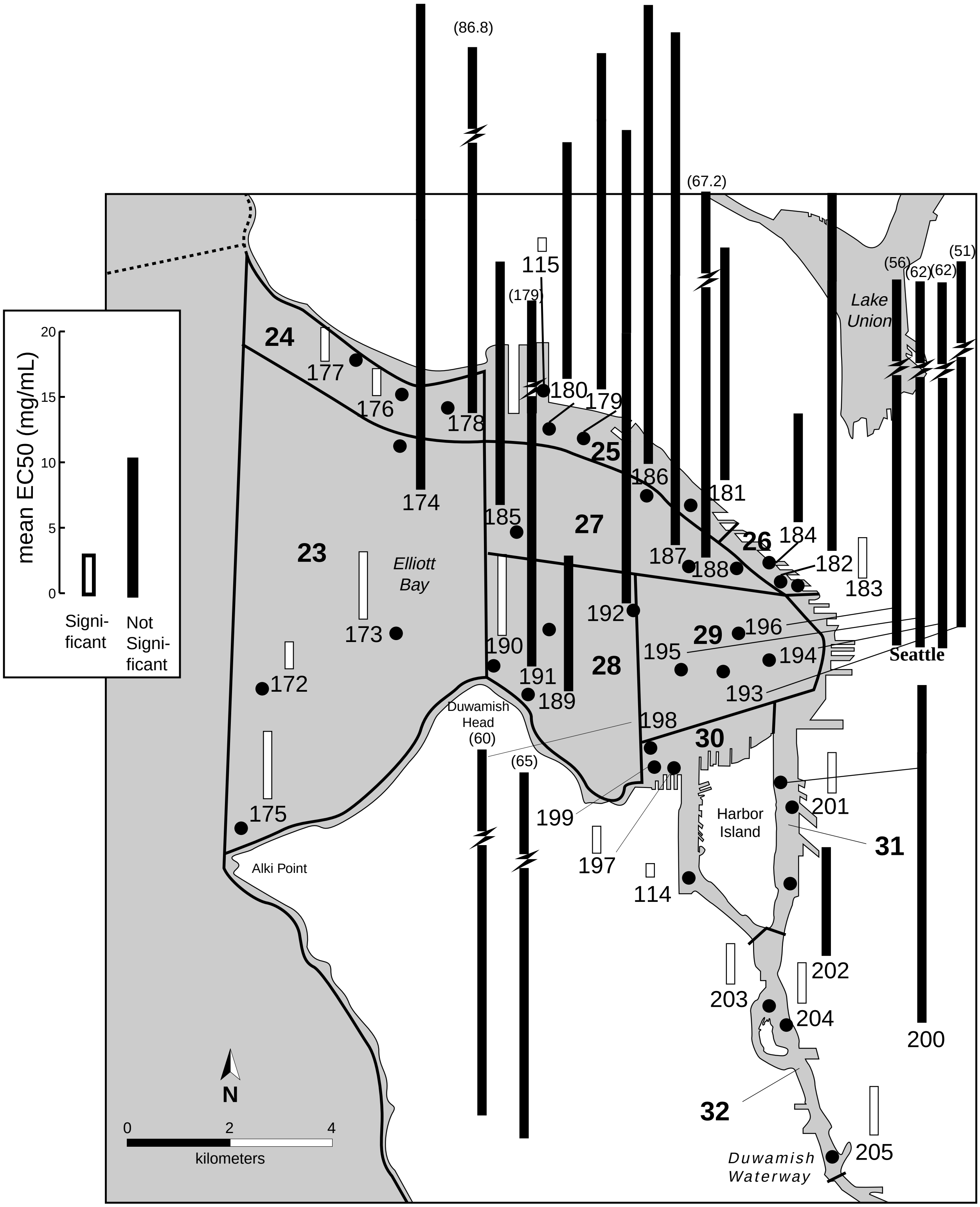


Figure 13. Results of 1998 Microtox™ bioluminescence tests for stations in Elliott Bay and the lower Duwamish River (strata 23 through 32). (Strata numbers are shown in bold. Stations are identified as sample number).

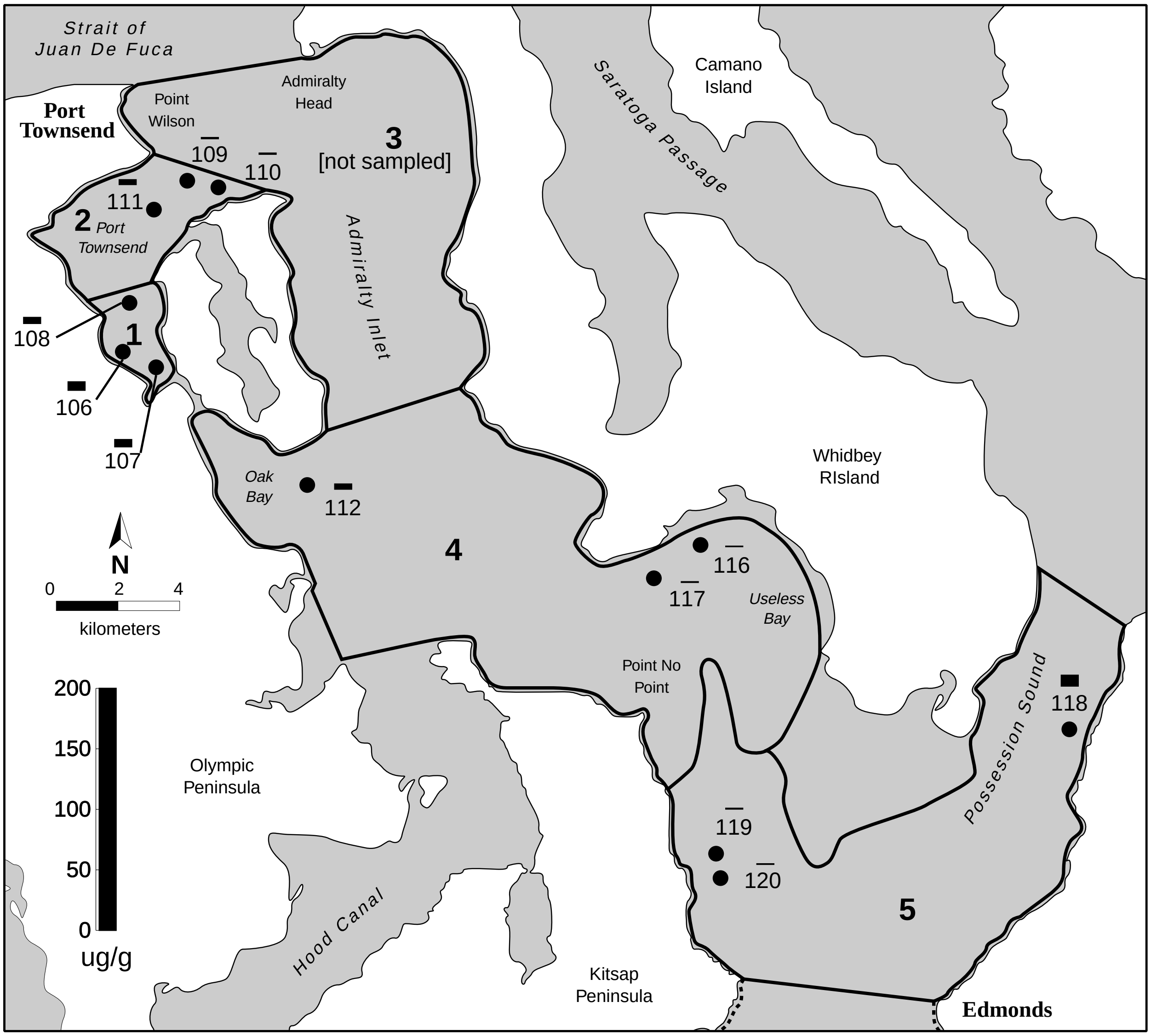


Figure 14. Results of 1998 cytochrome P450 HRGS assays (as B[a]P equivalents (µg/g)) for stations in Port Townsend to Possession Sound (strata 1 through 5). (Strata numbers are shown in bold. Stations are identified as sample number).

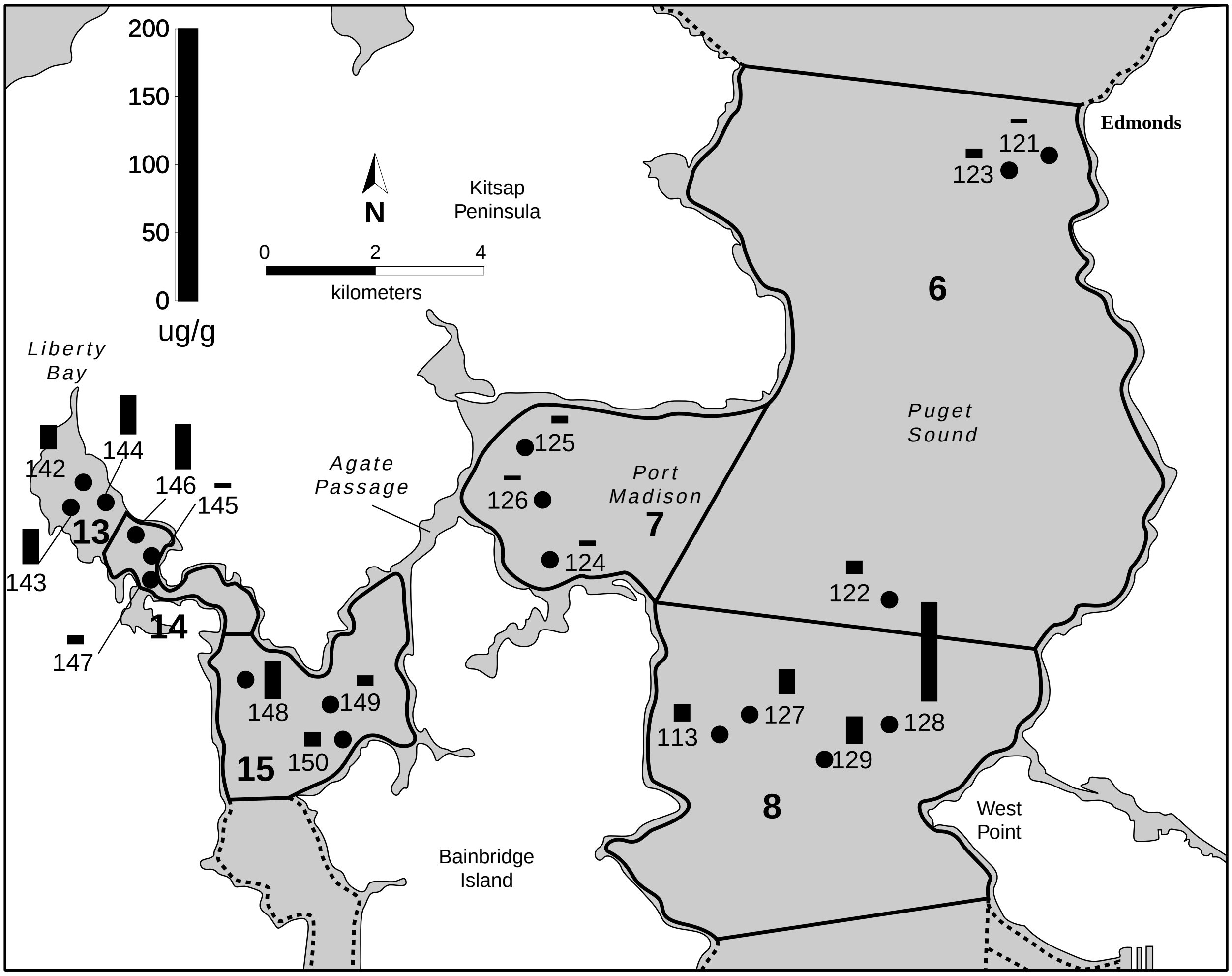


Figure 15. Results of 1998 cytochrome P450 HRGS assays (as B[a]P equivalents (μg/g)) for stations in Port Madison and central basin (strata 6 through 8) and Liberty Bay to Bainbridge Island (13 through 15). (Strata numbers are shown in bold. Stations are identified as sample number).

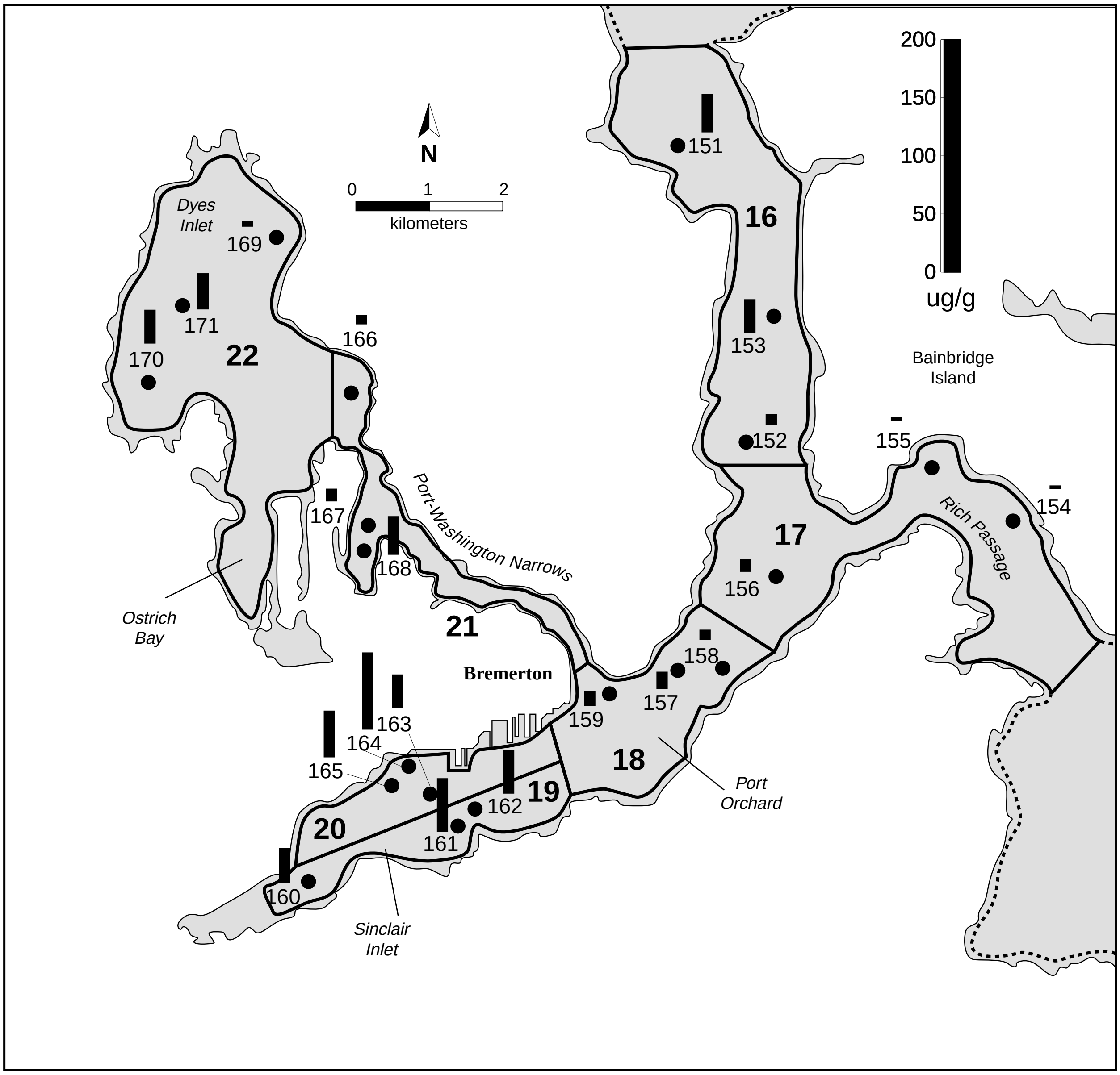


Figure 16. Results of 1998 cytochrome P450 HRGS assays (as B[a]P equivalents (µg/g)) for stations in Bremerton to Port Orchard (strata 16 through 22). (Strata numbers are shown in bold. Stations are identified as sample number).

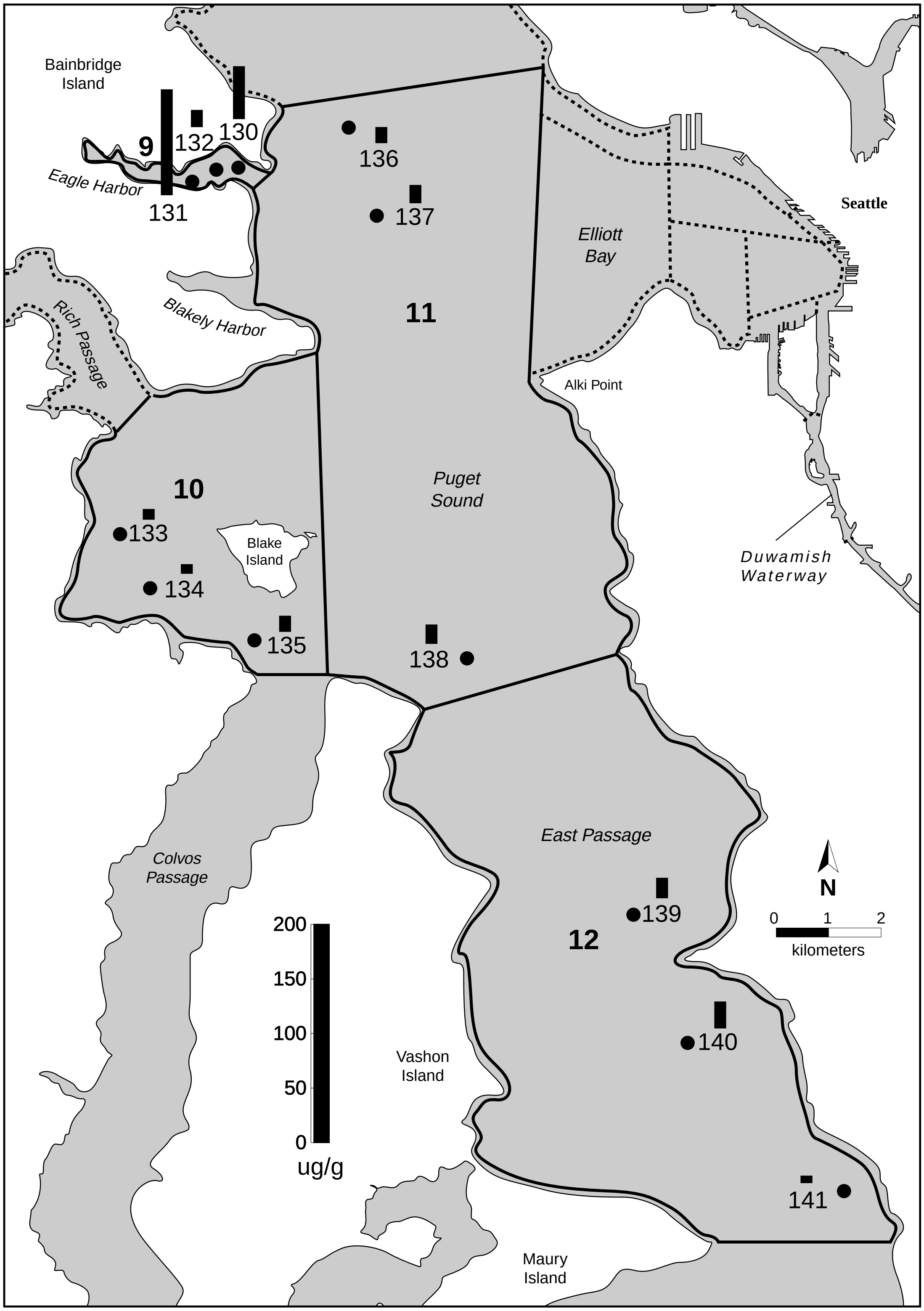


Figure 17. Results of 1998 cytochrome P450 HRGS assays (as B[a]P equivalents (µg/g)) for stations in Eagle Harbor, central basin, and East Passage (strata 9 through 12). (Strata numbers are shown in bold. Stations are identified as sample number).

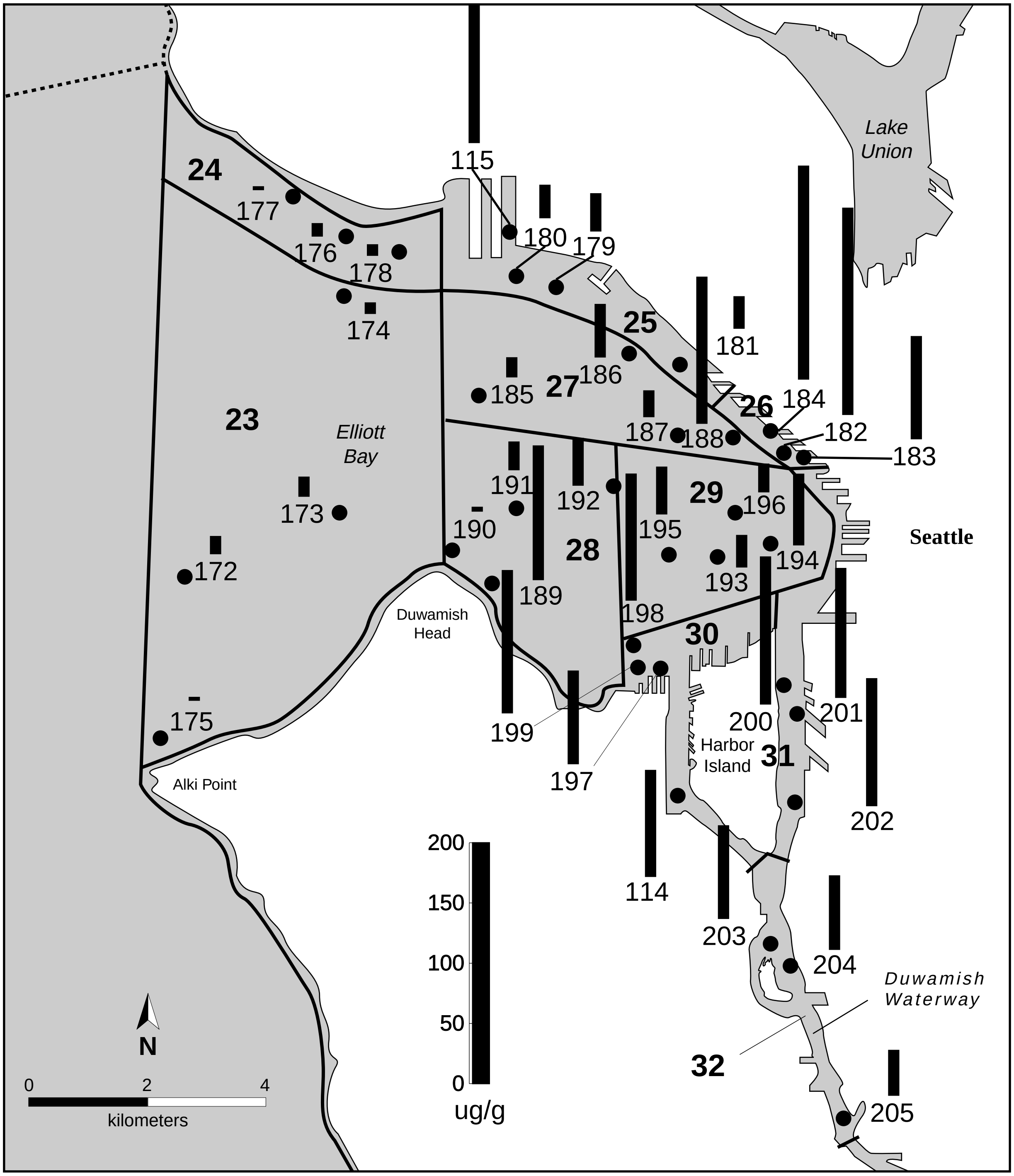


Figure 18. Results of 1998 cytochrome P450 HRGS assays (as B[a]P equivalents (µg/g)) for stations in Elliott Bay and the lower Duwamish River (strata 23 through 32). (Strata numbers are shown in bold. Stations are identified as sample number).

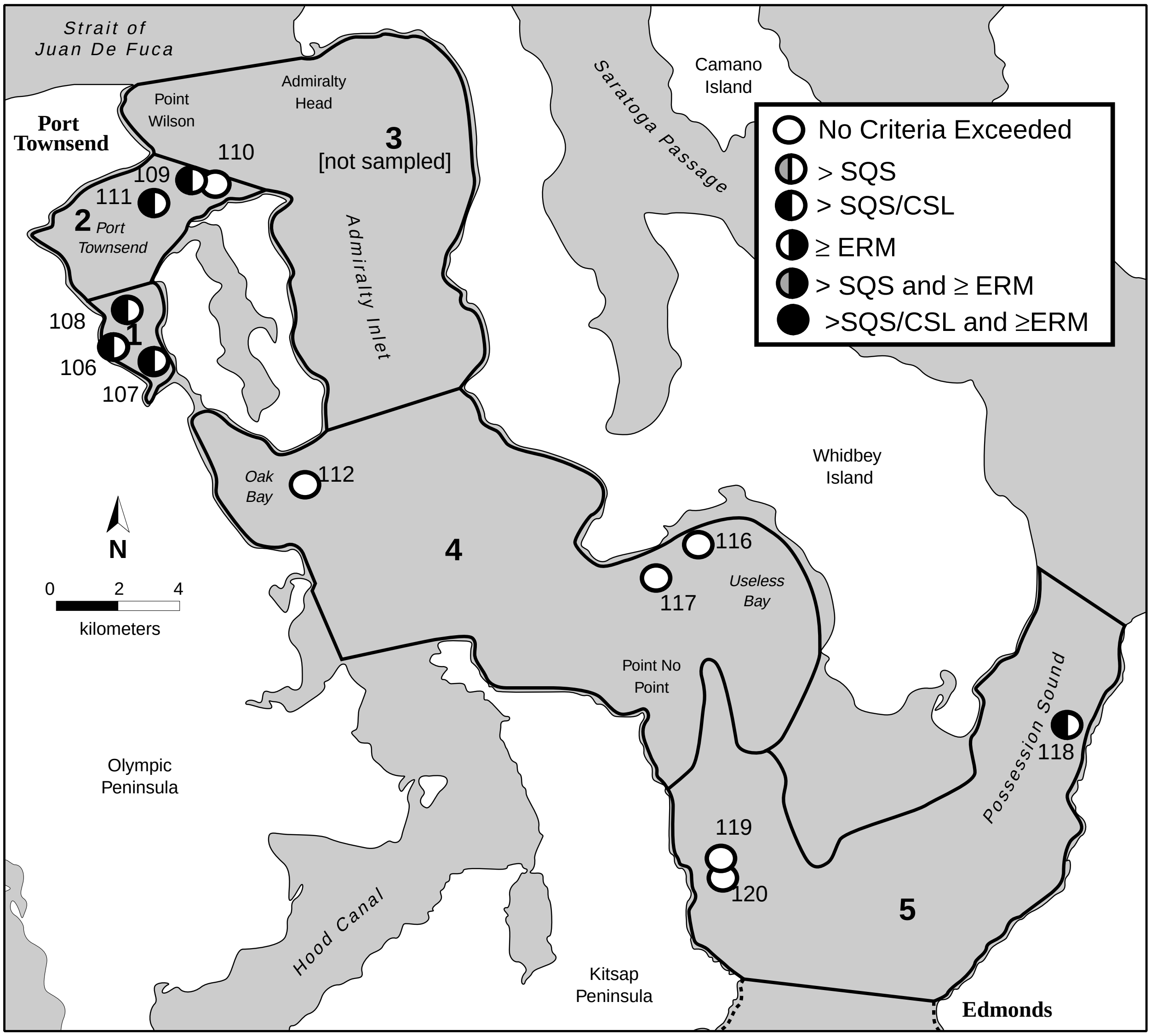


Figure 19. Sampling stations in Port Townsend to Possession Sound (strata 1 through 5) with sediment chemical concentrations exceeding numerical guidelines and Washington State criteria. (Strata numbers are shown in bold. Stations are identified as sample number).

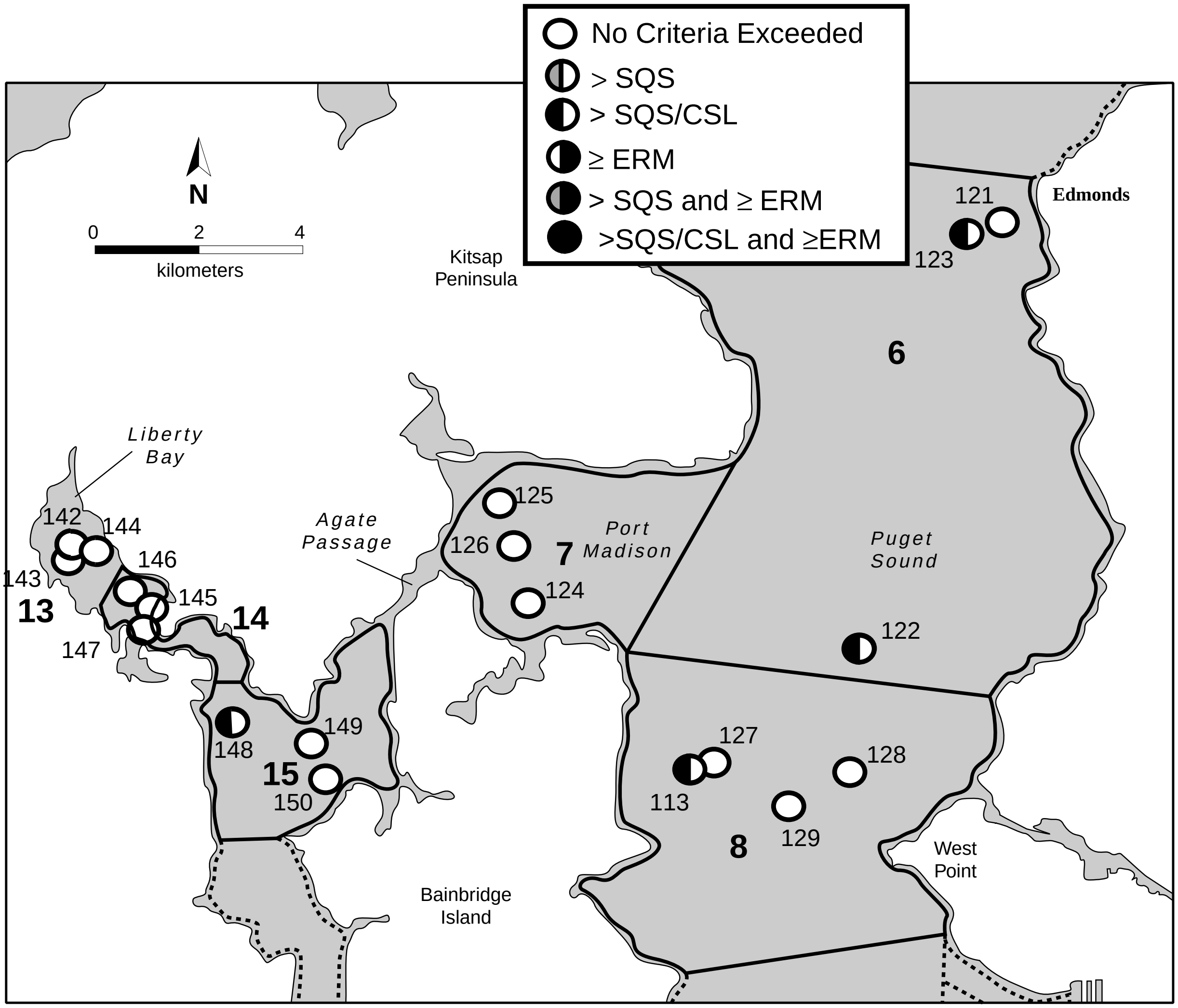


Figure 20. Sampling stations in Port Madison and central basin (strata 6 through 8) and Liberty Bay to Bainbridge Island (13 through 15) with sediment chemical concentrations exceeding numerical guidelines and Washington State criteria. (Strata numbers are shown in bold. Stations are identified as sample number).

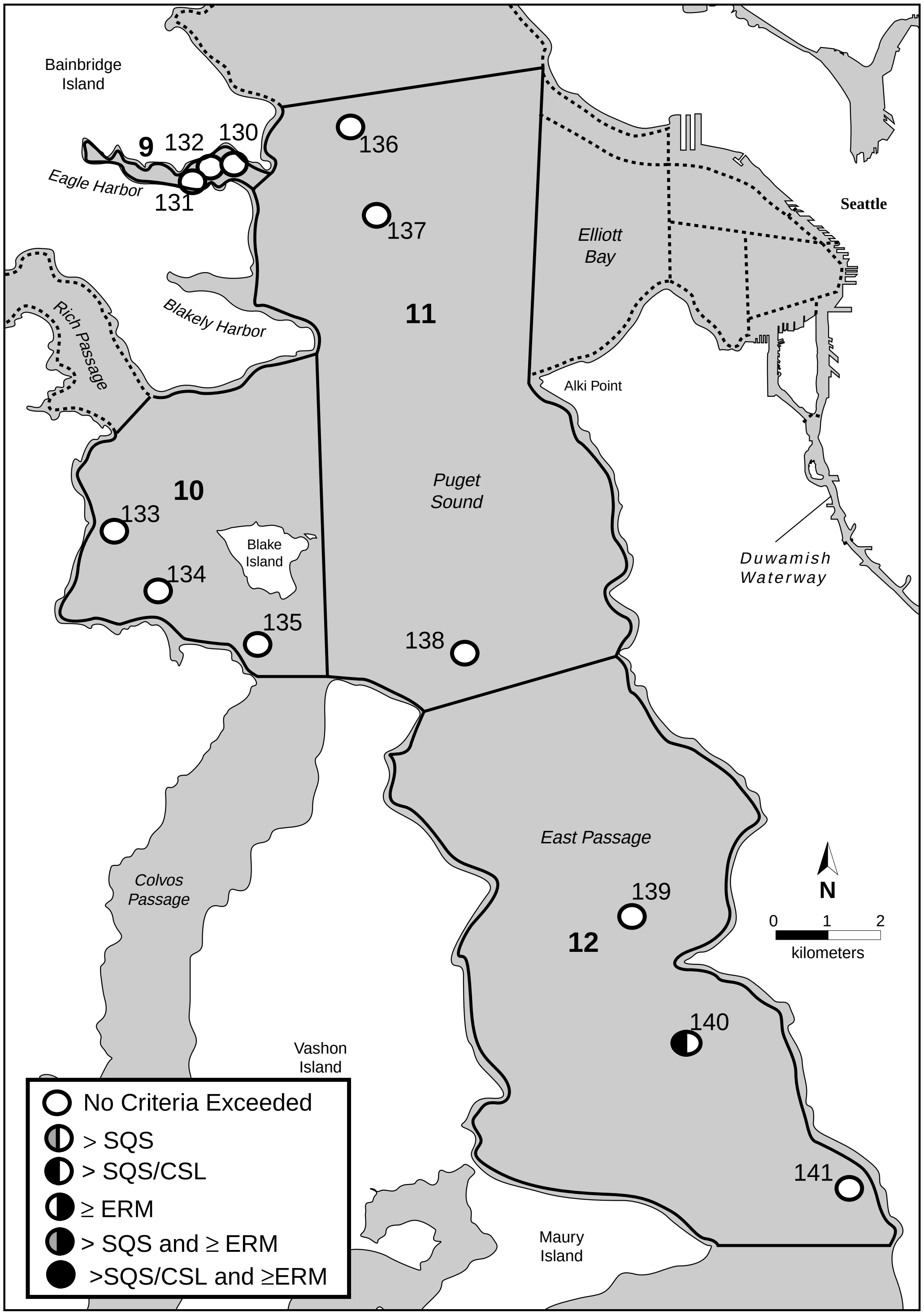


Figure 21. Sampling stations in Eagle Harbor, central basin, and East Passage (strata 9 through 12) with sediment chemical concentrations exceeding numerical guidelines and Washington State criteria. (Strata numbers are shown in bold. Stations are identified as sample number).

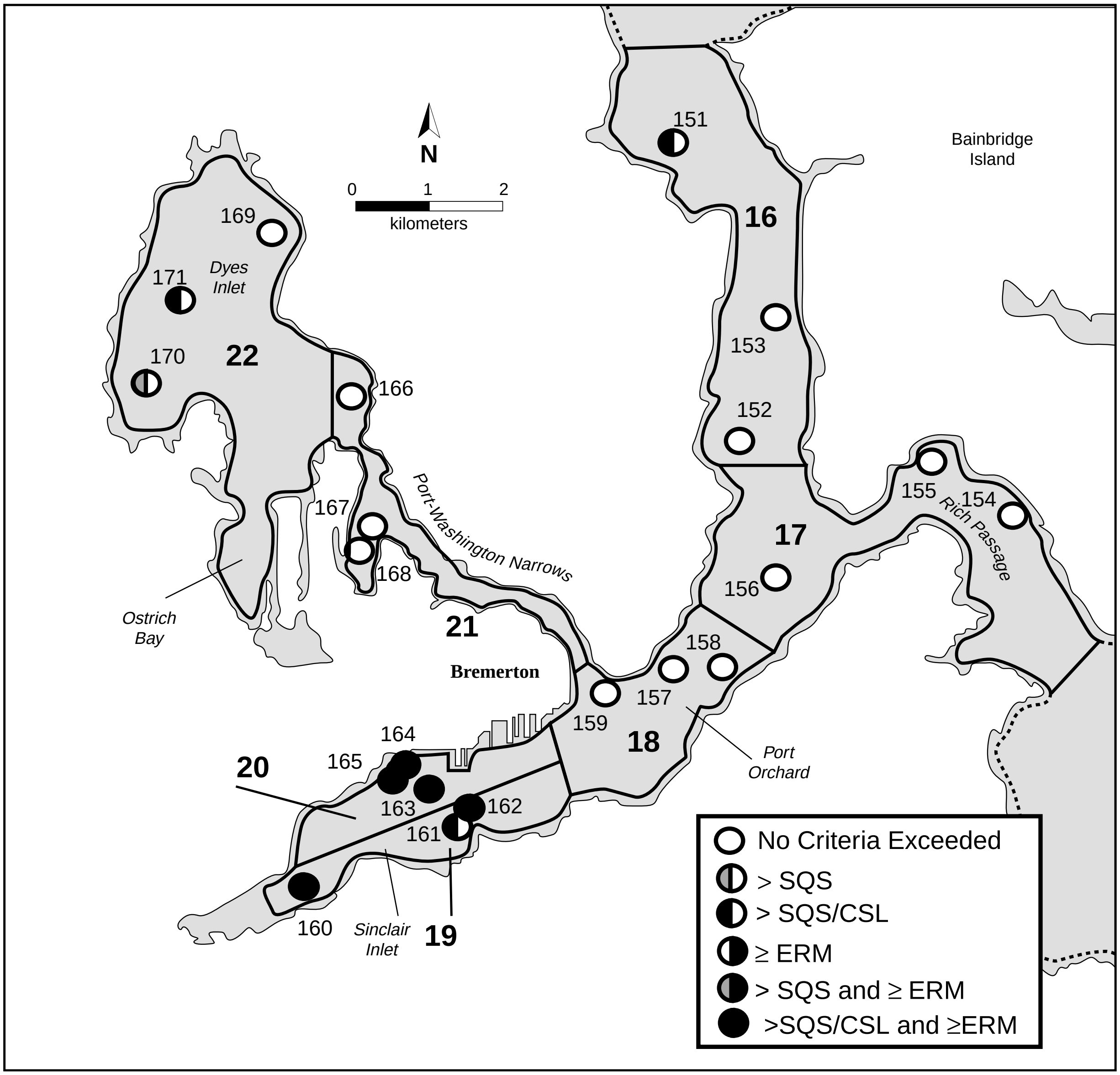


Figure 22. Sampling stations in Bremerton to Port Orchard (strata 16 through 22) with sediment chemical concentrations exceeding numerical guidelines and Washington State criteria. (Strata numbers are shown in bold. Stations are identified as sample number).

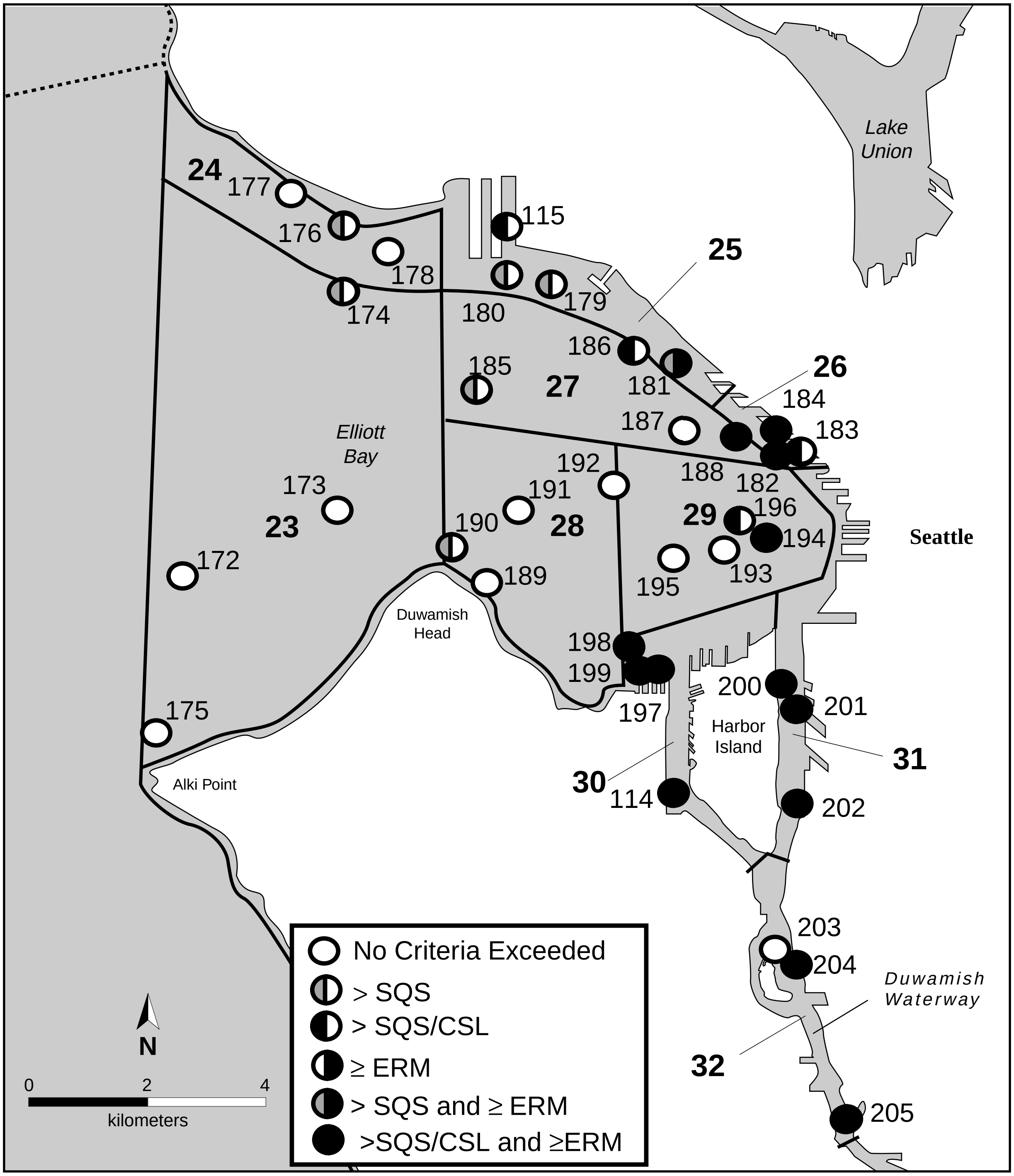


Figure 23. Sampling stations in Elliott Bay and the lower Duwamish River (strata 23 through 32) with sediment chemical concentrations exceeding numerical guidelines and Washington State criteria. (Strata numbers are shown in bold. Stations are identified as sample number).

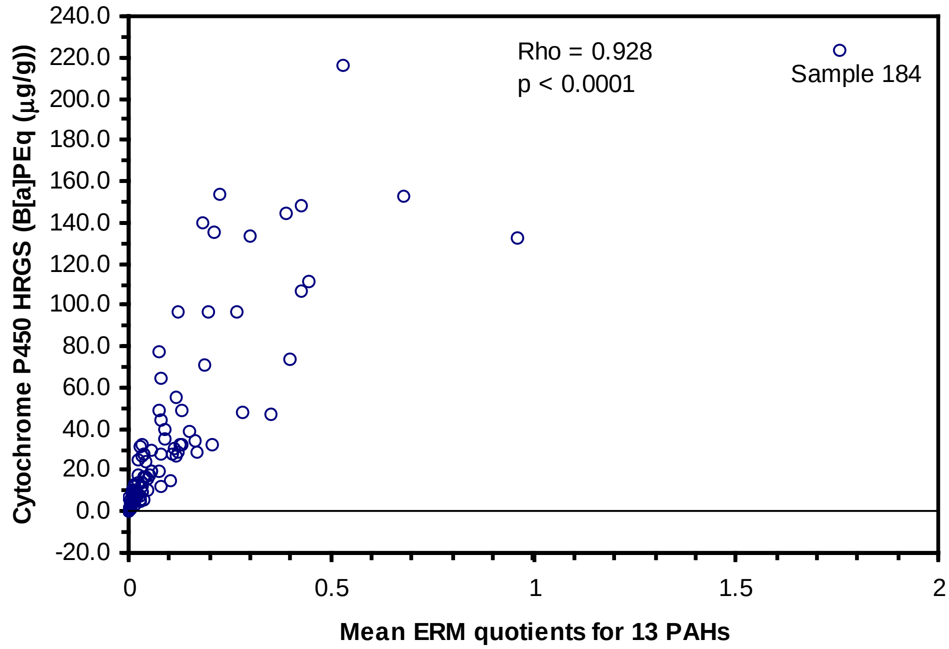


Figure 24. Relationship between cytochrome P450 HRGS and the mean ERM quotients for 13 polynuclear aromatic hydrocarbons in 1998 central Puget Sound sediments.

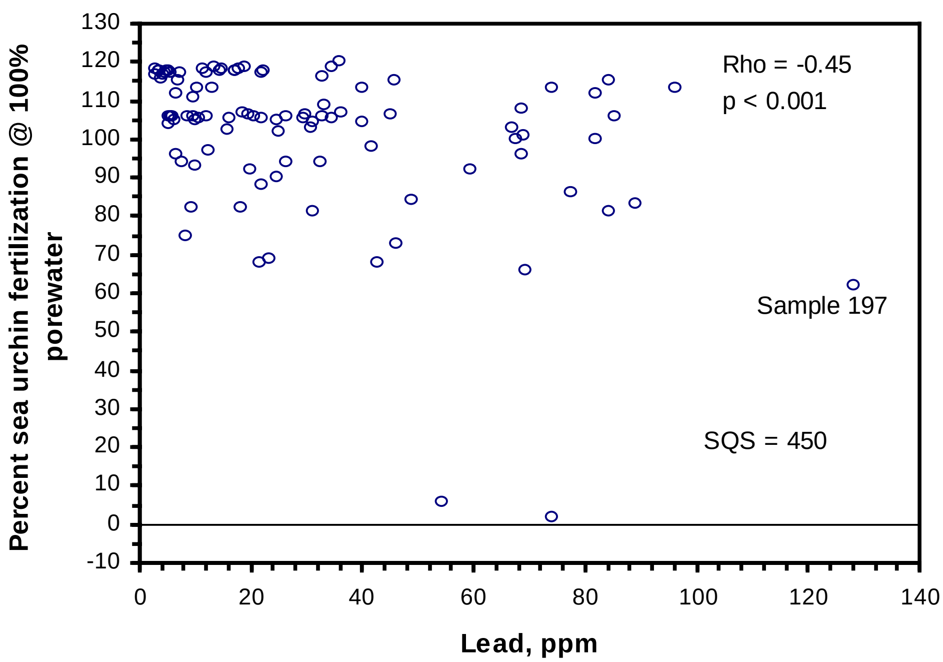


Figure 25. Relationship between sea urchin fertilization in pore water and concentrations of lead (partial digestion) in 1998 central Puget Sound sediments.

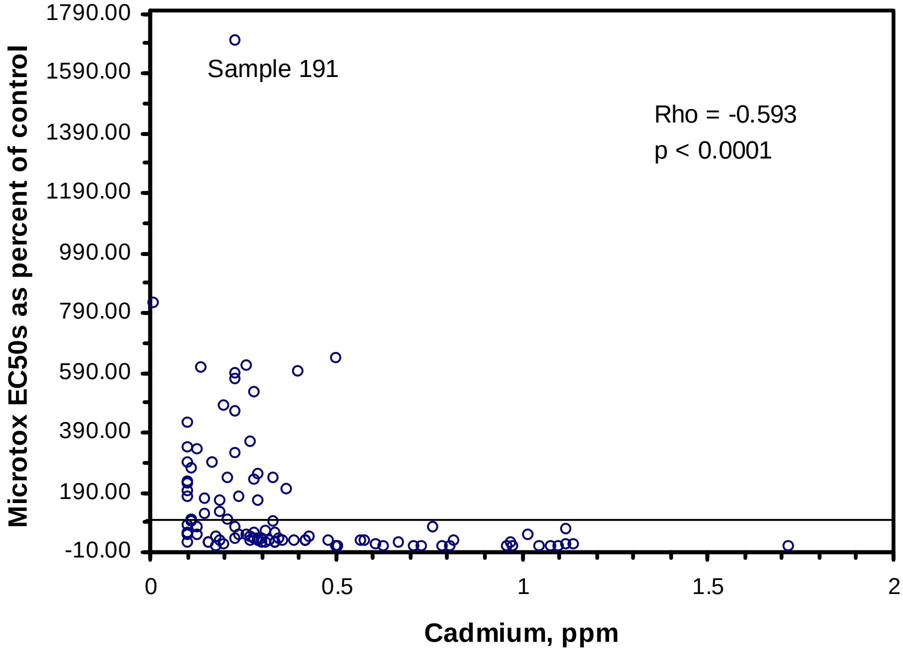


Figure 26. Relationship between microbial bioluminescence and concentrations of cadmium (partial digestion) in 1998 central Puget Sound sediments.

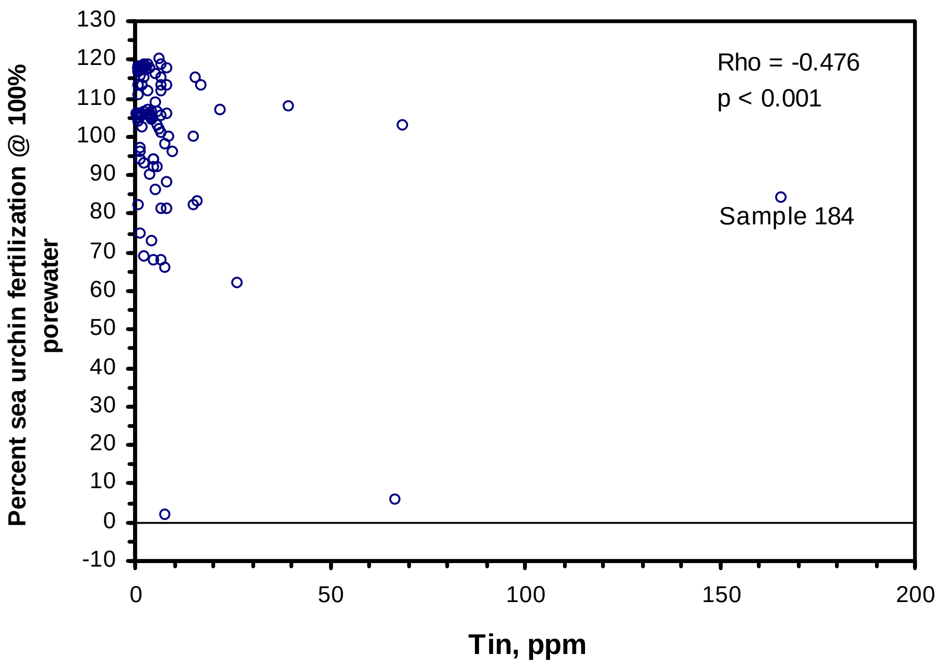


Figure 27. Relationship between sea urchin fertilization in pore water and concentrations of tin (total digestion) in 1998 central Puget Sound sediments.

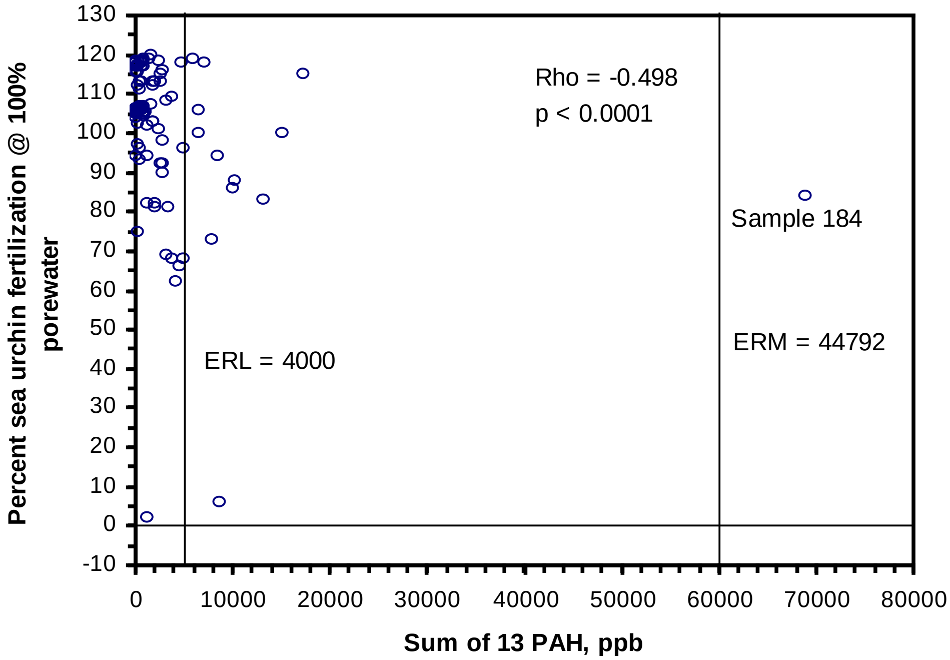


Figure 28. Relationship between sea urchin fertilization in pore water and the sum of 13 polynuclear aromatic hydrocarbons in 1998 central Puget Sound sediments.

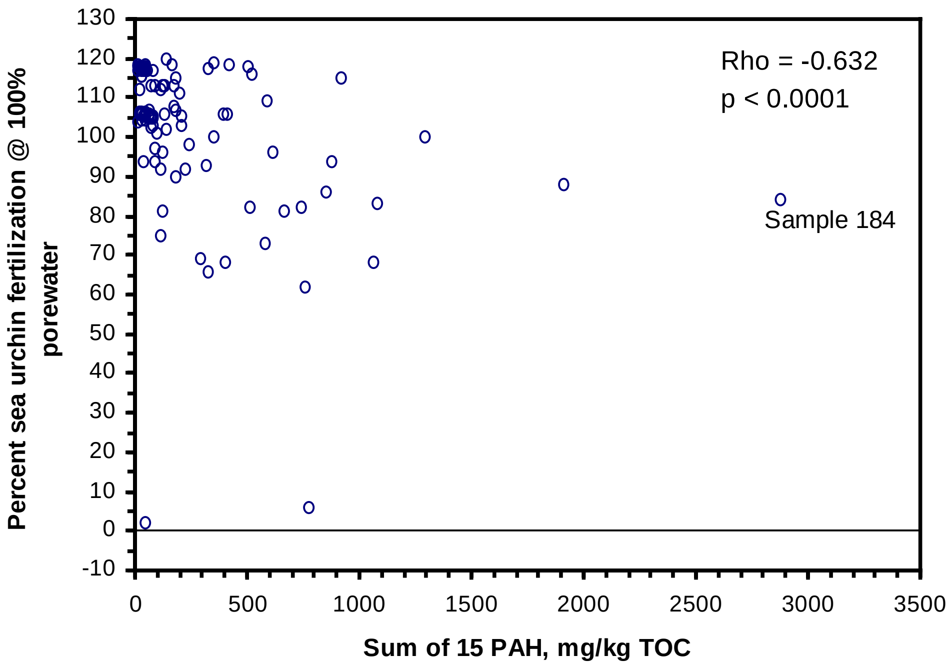


Figure 29. Relationship between sea urchin fertilization in pore water and the sum of 15 polynuclear aromatic hydrocarbons in 1998 central Puget Sound sediments.

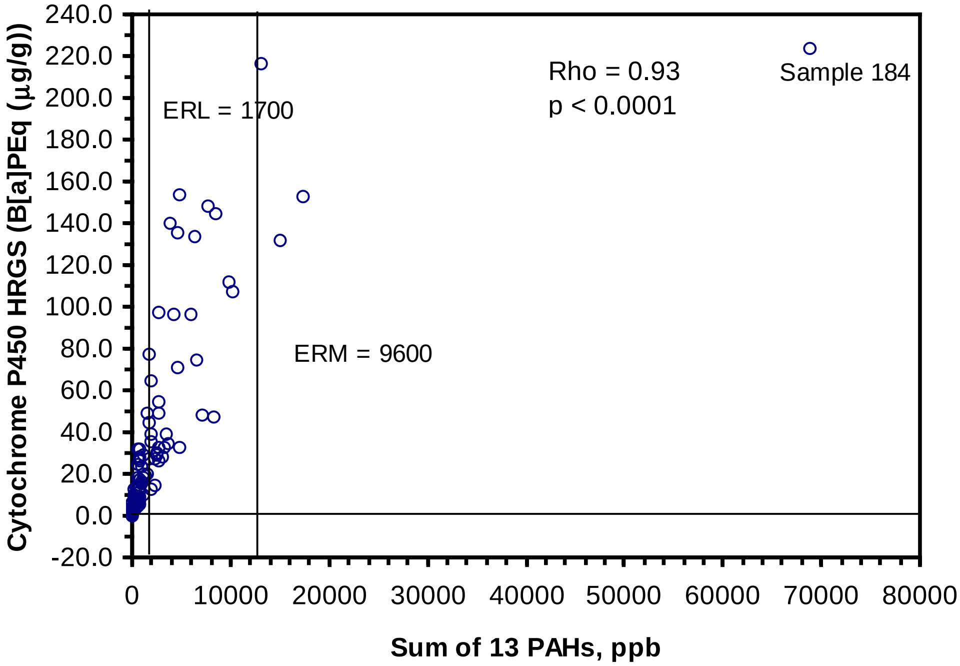


Figure 30. Relationship between cytochrome P450 HRGS and the sum of 13 polynuclear aromatic hydrocarbons in 1998 central Puget Sound sediments.

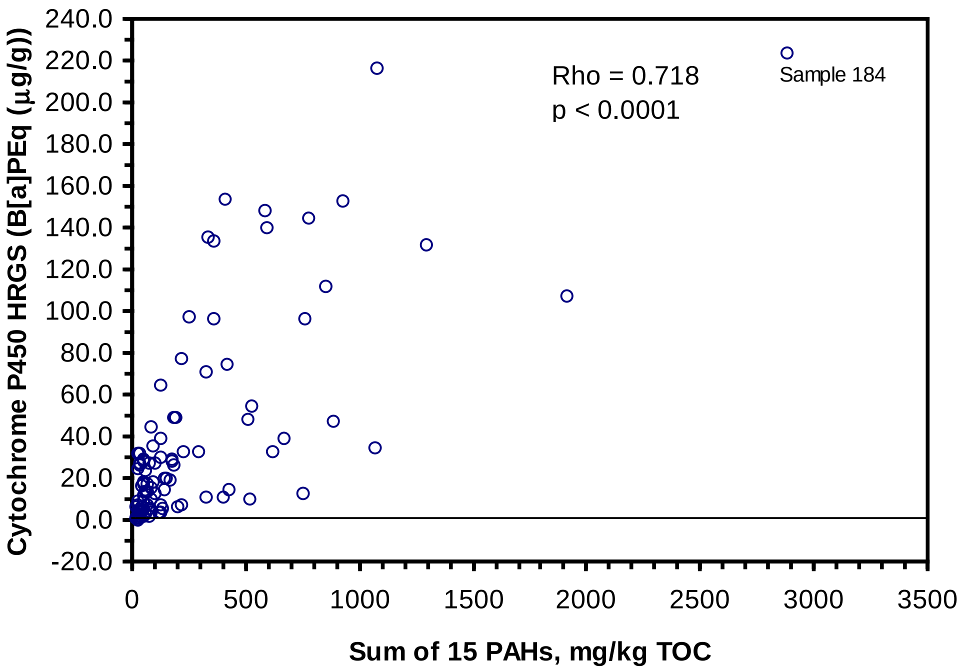


Figure 31. Relationship between cytochrome P450 HRGS and the sum of 15 polynuclear aromatic hydrocarbons in 1998 central Puget Sound sediments.

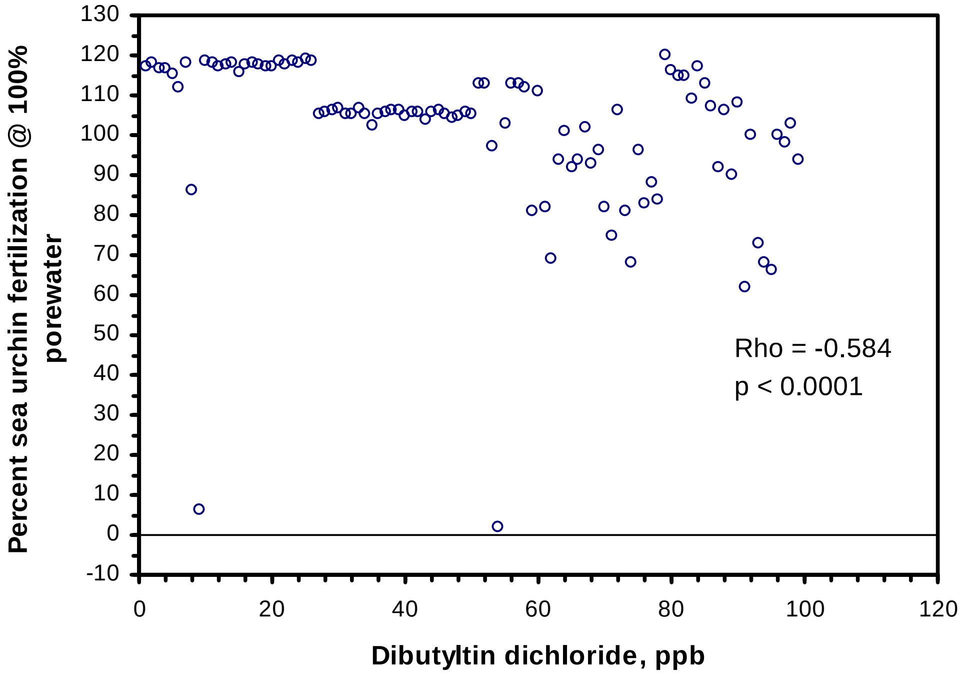


Figure 32. Relationship between urchin fertilization and concentrations of dibutyltin in 1998 central Puget Sound sediments.

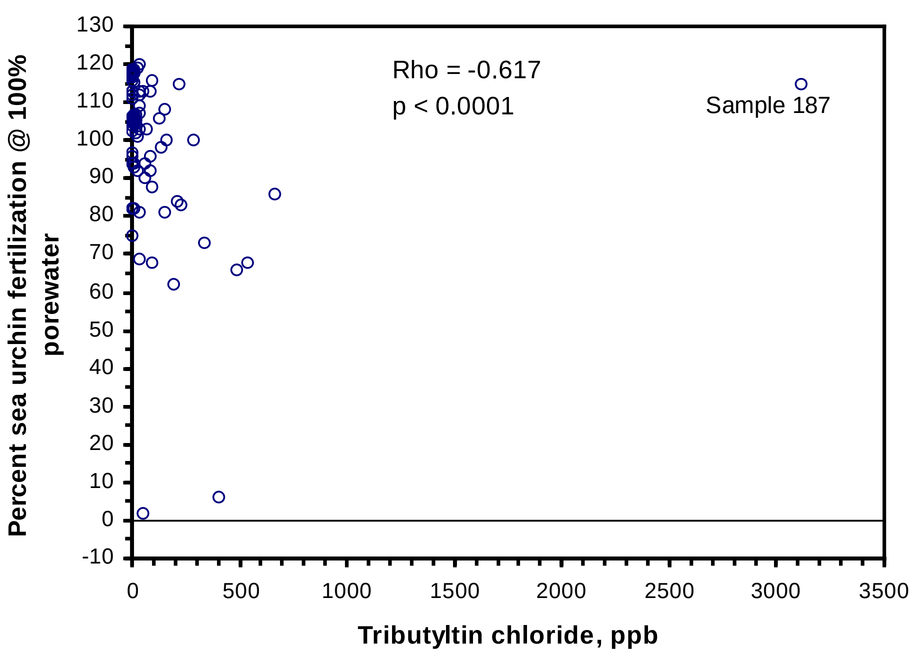


Figure 33. Relationship between urchin fertilization and concentrations of tributyltin in 1998 central Puget Sound sediments.

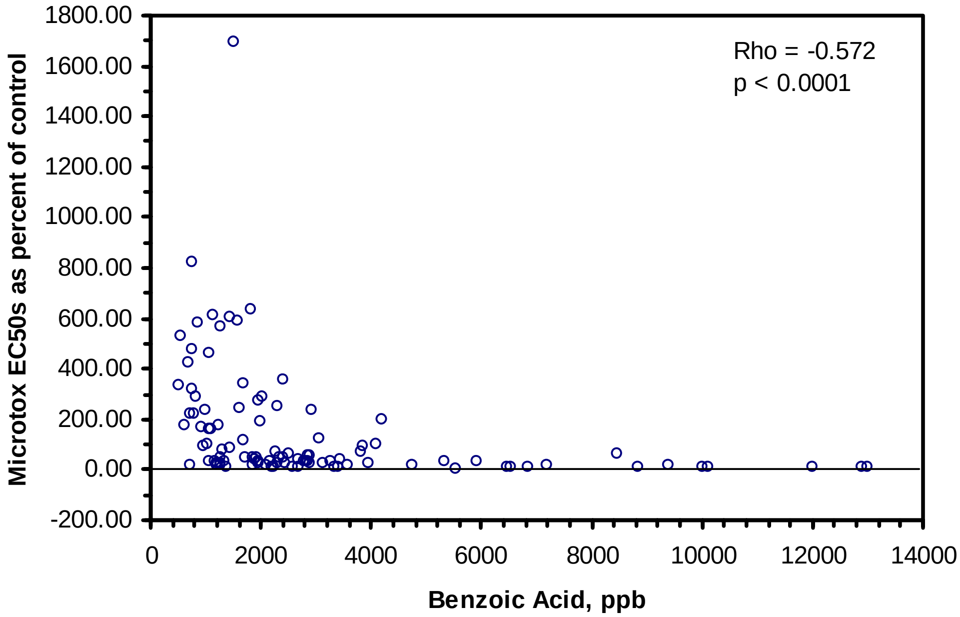


Figure 34. Relationship between microbial bioluminescence and concentrations of benzoic acid in 1998 central Puget Sound sediments.

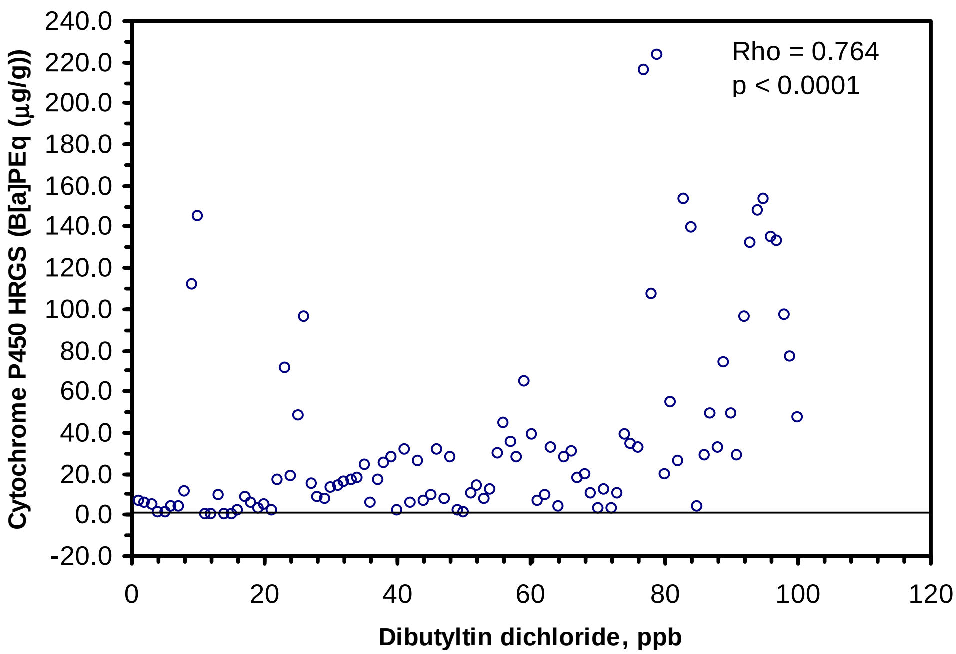


Figure 35. Relationship between cytochrome P450 HRGS and concentrations of dibutyltin in 1998 central Puget Sound sediments.

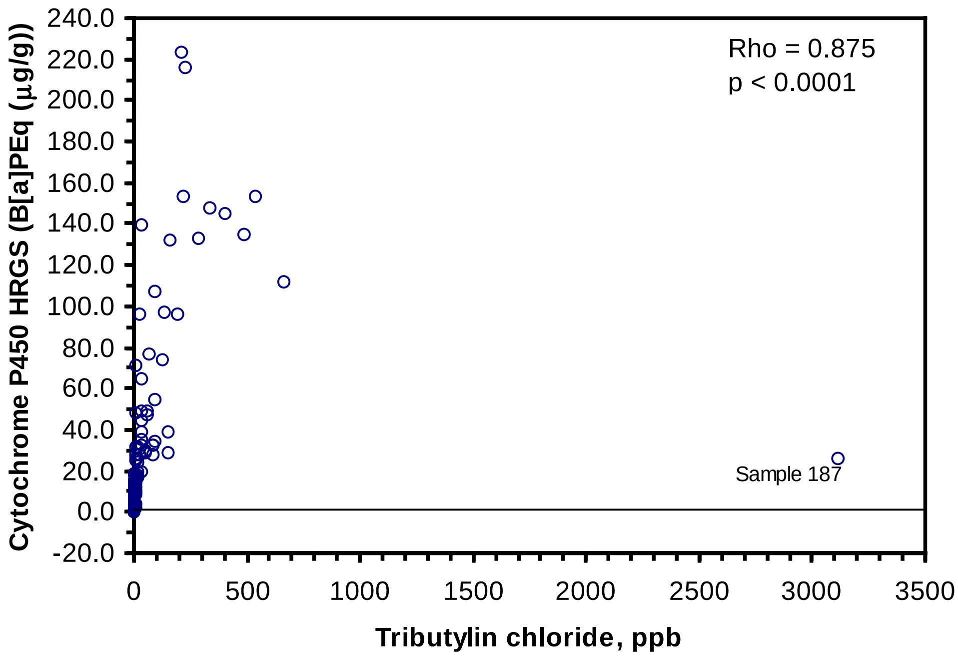


Figure 36. Relationship between cytochrome P450 HRGS and concentrations of tributyltin in 1998 central Puget Sound sediments.

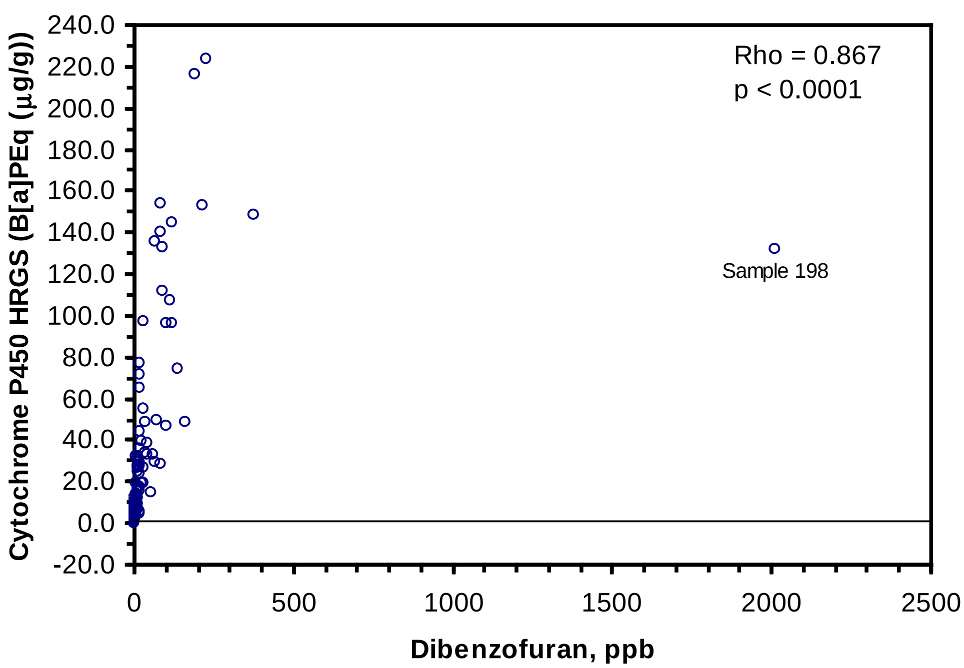


Figure 37. Relationship between cytochrome P450 HRGS and concentrations of dibenzofuran in 1998 central Puget Sound sediments.

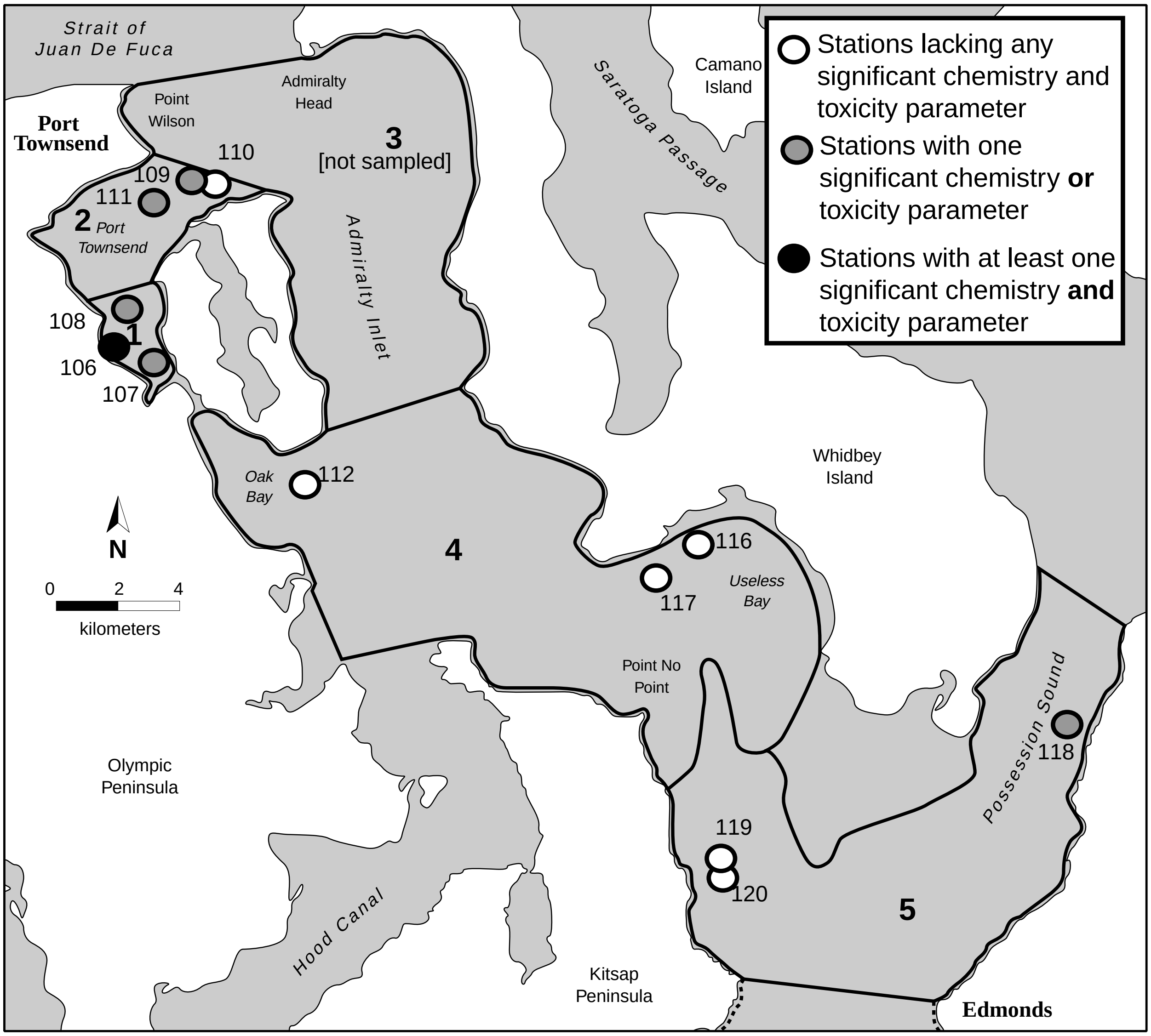


Figure 38. Central Puget Sound stations for the 1998 PSAMP/NOAA Bioeffects Survey with significant results and stations with non-significant results for chemistry and toxicity tests, Port Townsend to Possession Sound (strata 1 through 5). (Strata numbers are shown in bold. Stations are identified as sample number).

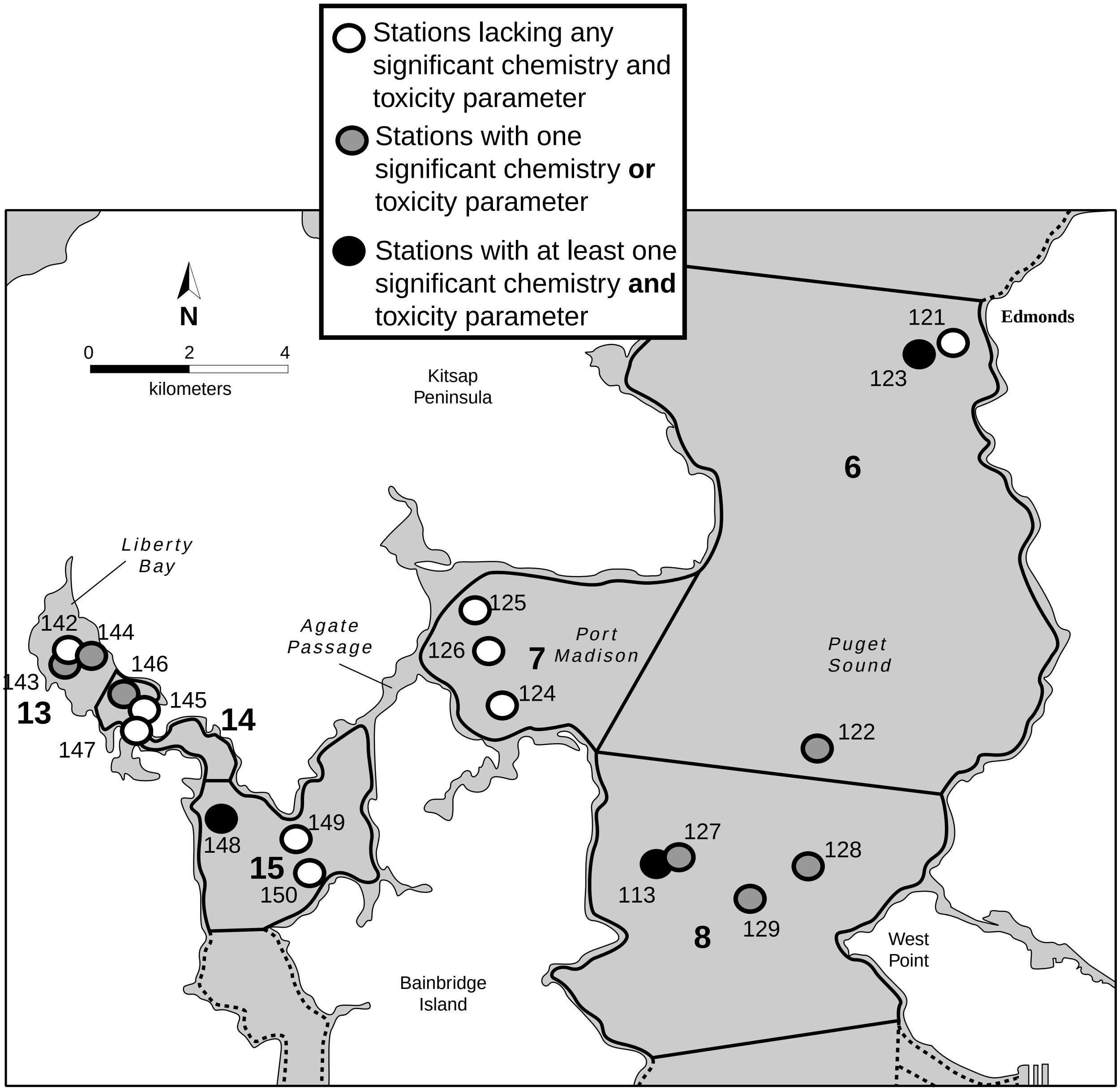


Figure 39. Central Puget Sound stations for the 1998 PSAMP/NOAA Bioeffects Survey with significant results and stations with non-significant results for chemistry and toxicity tests, Port Madison and central basin (strata 6 through 8) and Liberty Bay to Bainbridge Island (13 through 15). (Strata numbers are shown in bold. Stations are identified as sample number).

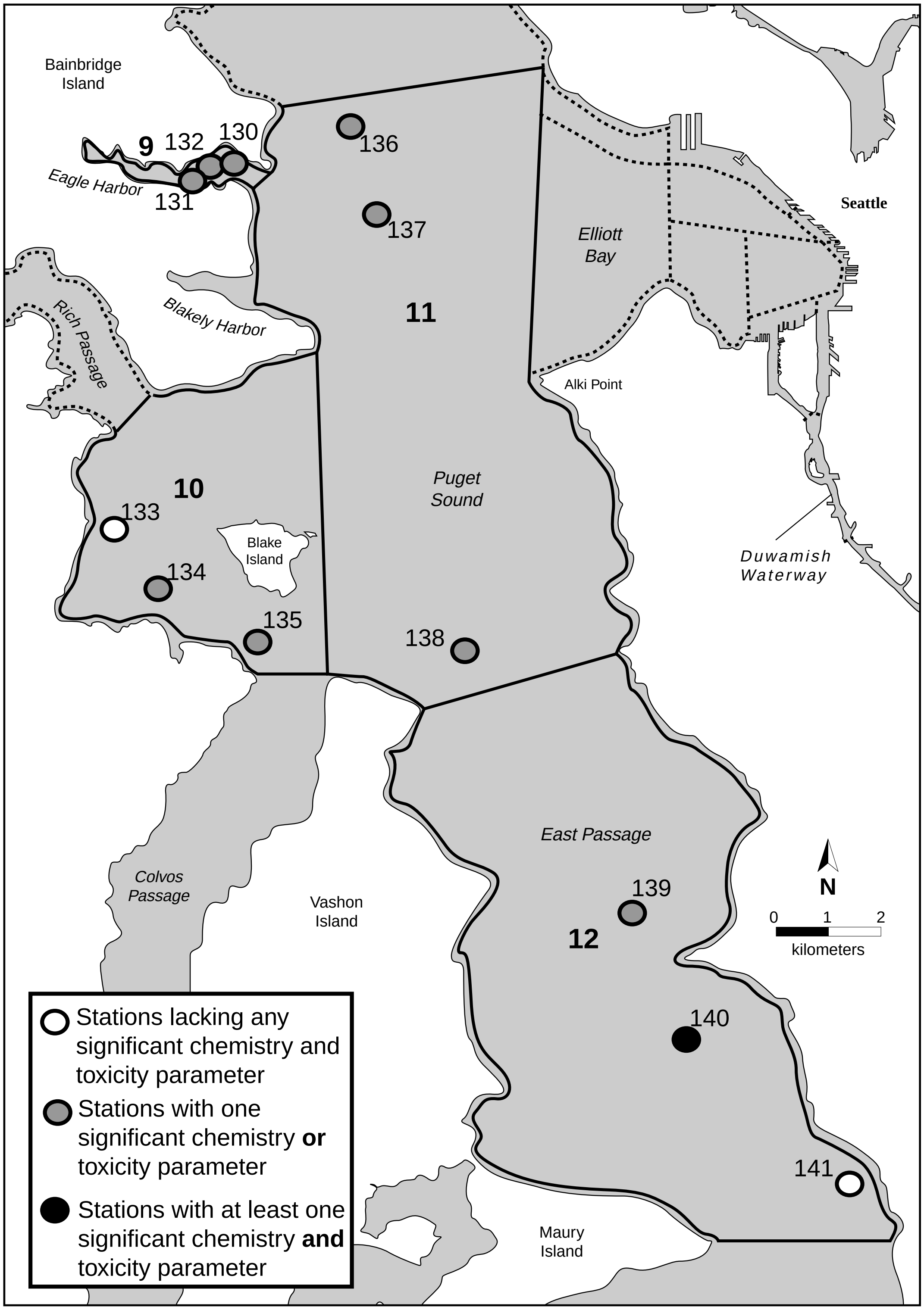


Figure 40. Central Puget Sound stations for the 1998 PSAMP/NOAA Bioeffects Survey with significant results and stations with non-significant results for chemistry and toxicity tests, Eagle Harbor, central basin, and East Passage (strata 9 through 12). (Strata numbers are shown in bold. Stations are identified as sample number).

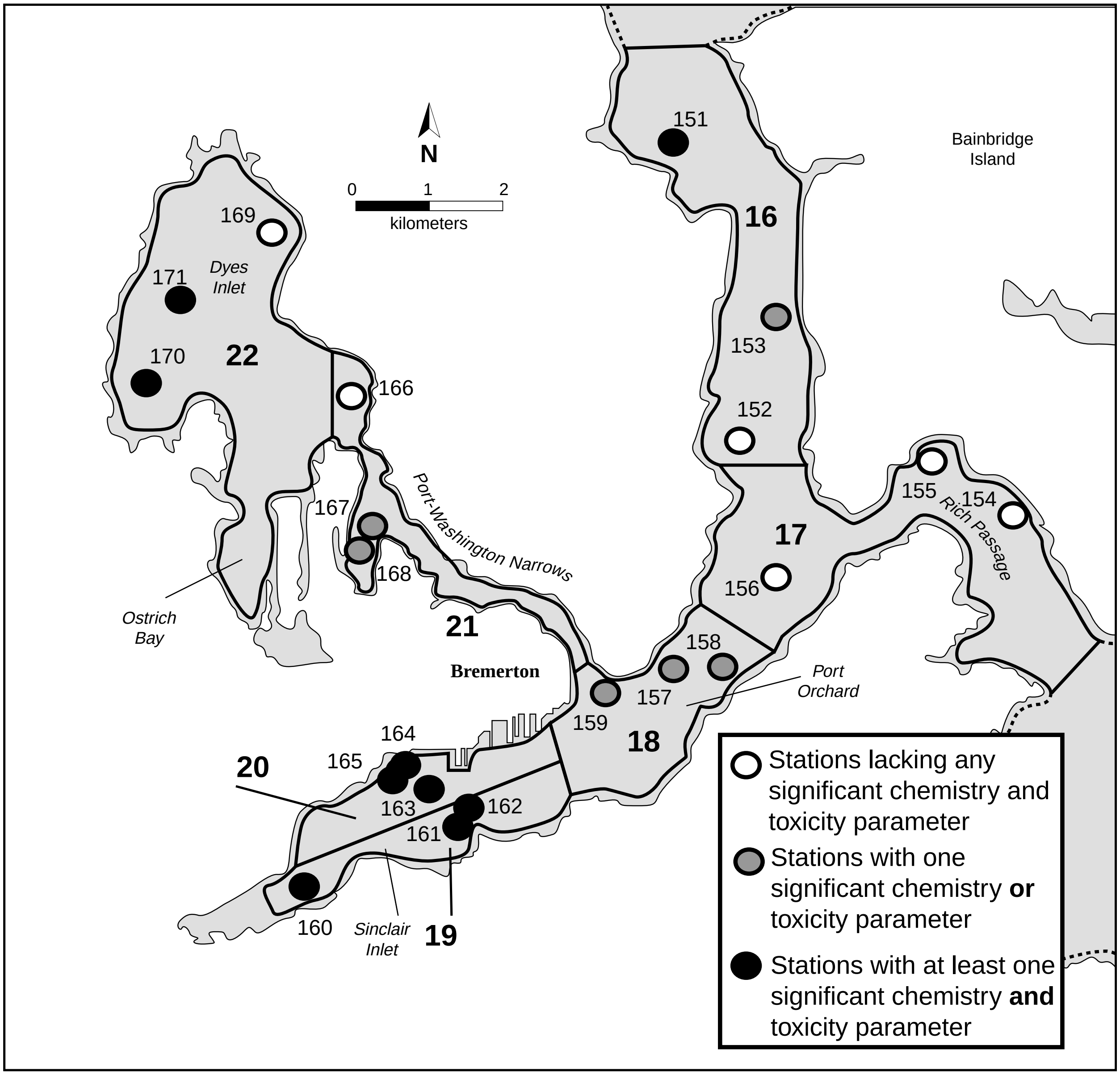


Figure 41. Central Puget Sound stations for the 1998 PSAMP/NOAA Bioeffects Survey with significant results and stations with non-significant results for chemistry and toxicity tests, Bremerton to Port Orchard (strata 16 through 22). (Strata numbers are shown in bold. Stations are identified as sample number).

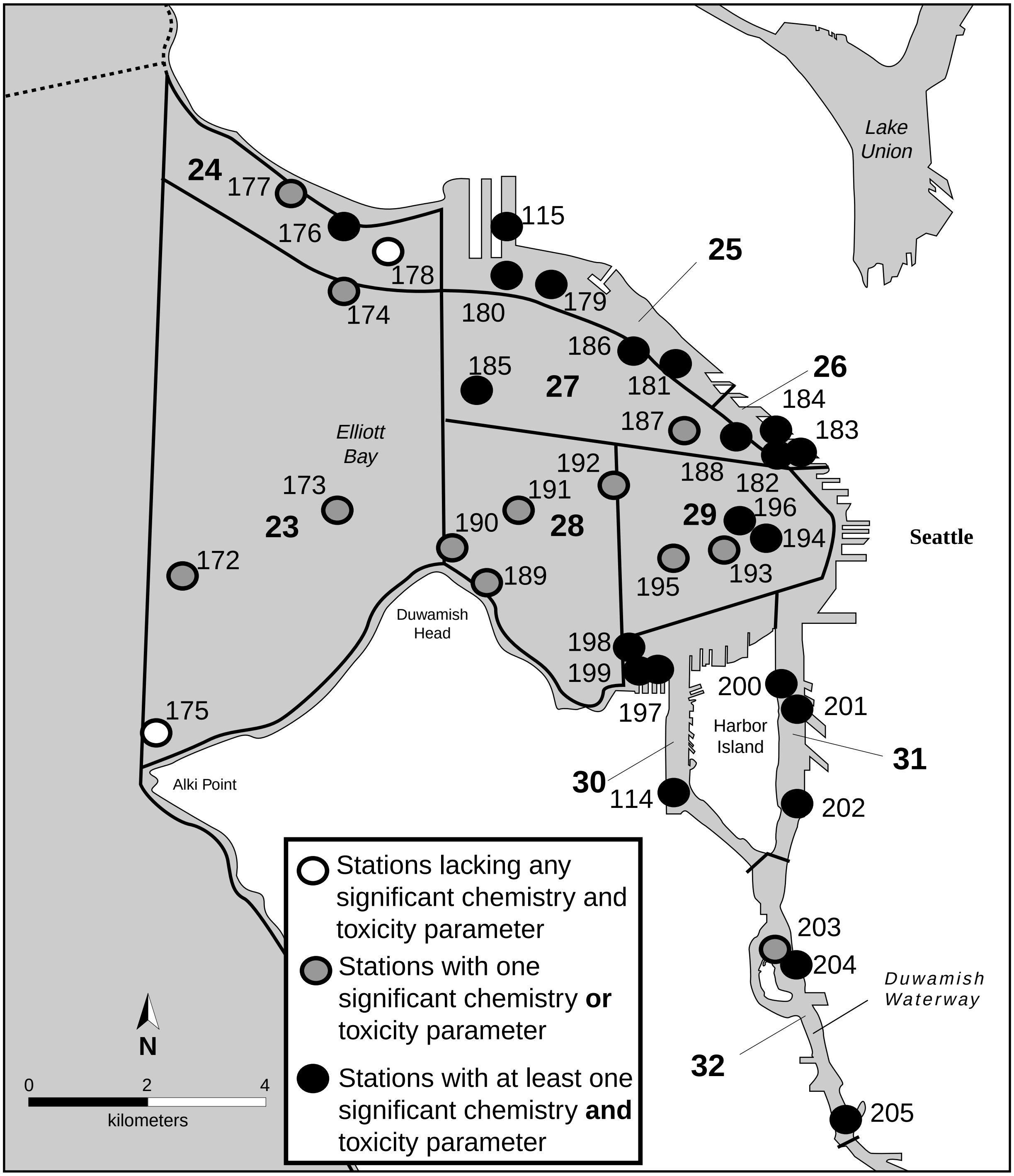


Figure 42. Central Puget Sound stations for the 1998 PSAMP/NOAA Bioeffects Survey with significant results and stations with non-significant results for chemistry and toxicity tests, Elliott Bay and the lower Duwamish River (strata 23 through 32). (Strata numbers are shown in bold. Stations are identified as sample number).

Table 1. Central Puget Sound sampling strata for the PSAMP/NOAA Bioeffects Survey.

Stratum Number	Stratum Name	Area (km^2) ($731.66\ km^2$)	% of Total Area
1	South Port Townsend	8.02	1.10
2	Port Townsend	19.52	2.67
3	North Admiralty Inlet*		
4	South Admiralty Inlet	158.83	21.71
5	Possession Sound	120.45	16.46
6	Central Basin	87.79	12.00
7	Port Madison	16.43	2.25
8	West Point	45.72	6.25
9	Eagle Harbor	1.21	0.17
10	Central Basin	27.90	3.81
11	Central Basin	77.14	10.54
12	East Passage	77.35	10.57
13	Liberty Bay	1.95	0.27
14	Keyport	2.82	0.39
15	North West Bainbridge Island	13.26	1.81
16	South West Bainbridge Island	10.26	1.40
17	Rich Passage	10.02	1.37
18	Port Orchard	5.82	0.80
19	Sinclair Inlet	3.09	0.42
20	Sinclair Inlet	3.12	0.43
21	Port Washington Narrows	3.00	0.41
22	Dyes Inlet	11.64	1.59
23	Outer Elliott Bay	11.16	1.53
24	Shoreline Elliott Bay	1.26	0.17
25	Shoreline Elliott Bay	1.32	0.18
26	Shoreline Elliott Bay	0.33	0.05
27	Mid Elliott Bay	4.16	0.57
28	Mid Elliott Bay	2.80	0.38
29	Mid Elliott Bay	2.92	0.40
30	West Harbor Island	1.08	0.15
31	East Harbor Island	0.54	0.07
32	Duwamish	0.75	0.10

*This stratum was eliminated during the course of sampling due to the rocky nature of the substratum.

Table 2. Chemical and physical analyses conducted on sediments collected from central Puget Sound.

Related Parameters
Grain Size
Total organic carbon

Metals

Ancillary Metals
Aluminum
Barium
Boron
Calcium
Cobalt
Iron
Magnesium
Manganese
Potassium
Sodium
Strontium
Titanium
Vanadium

Priority Pollutant Metals
Antimony
Arsenic
Beryllium
Cadmium
Chromium
Copper
Lead
Mercury
Nickel
Selenium
Silver
Thallium
Zinc

Major Elements
Silicon

Trace Elements
Tin

Organics

Chlorinated Alkanes
Hexachlorobutadiene

Chlorinated and Nitro-Substituted Phenols
Pentachlorophenol

Chlorinated Aromatic Compounds
1,2,4-trichlorobenzene
1,2-dichlorobenzene
1,3-dichlorobenzene
1,4-dichlorobenzene
2-chloronaphthalene
Hexachlorobenzene

Chlorinated Pesticides
2,4'-DDD
2,4'-DDE
2,4'-DDT
4,4'-DDD
4,4'-DDE
4-4'DDT
Aldrin
Alpha-chlordane
Alpha-HCH
Beta-HCH
Chlorpyrifos
Cis-nonachlor
Delta-HCH
Dieldrin
Endosulfan I (Alpha-endosulfan)
Endosulfan II (Beta-endosulfan)
Endosulfan sulfate
Endrin
Endrin ketone
Endrin aldehyde
Gamma-chlordane
Gamma-HCH
Heptachlor
Heptachlor epoxide
Methoxychlor
Mirex

Table 2. Continued.

Oxychlordane
Toxaphene
Trans-nonachlor

Polynuclear Aromatic Hydrocarbons
LPAHs
1,6,7-Trimethylnaphthalene
1-Methylnaphthalene
1-Methylphenanthrene
2,6-Dimethylnaphthalene
2-methylnapthalene
2-methylphenanthrene
Acenaphthene
Acenaphthylene
Anthracene
Biphenyl
C1 - C3 Fluorenes
C1 - C3 Dibenzothiophenes
C1 - C4 Naphthalenes
C1 - C4 Phenanthrenes
Dibenzothiophene
Fluorene
Naphthalene
Phenanthrene
Retene
calculated value:
LPAH
HPAHs
Benzo(a)anthracene
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo(e)pyrene
Benzo(g,h,i)perylene
Benzo(k)fluoranthene
C1 - C4 Chrysene
C1- Fluoranthene
Chrysene
Dibenzo(a,h)anthracene
Fluoranthene
Indeno(1,2,3-c,d)pyrene
Perylene
Pyrene
calculated values:
total Benzofluoranthenes
HPAH

Miscellaneous Extractable Compounds
Benzoic acid
Benzyl alcohol
Dibenzofuran

Organonitrogen Compounds
N-nitrosodiphenylamine

Organotins
Butyl tins: Di-, Tri-butyltin

Phenols
2,4-dimethylphenol
2-methylphenol
4-methylphenol
Phenol
P-nonylphenol

Phthalate Esters
Bis(2-ethylhexyl)phthalate
Butyl benzyl phthalate
Diethyl phthalate
Dimethyl phthalate
Di-n-butyl phthalate
Di-n-octyl phthalate

Polychlorinated Biphenyls
PCB Congeners:
8
18
28
44
52
66
77
101
105
118
126
128
138
153
170
180
187

Table 2. Continued.

PCB Congeners, continued:
195
206
209

PCB Aroclors:
1016
1221
1232
1242
1248
1254
1260

Table 3. Chemistry Parameters: Laboratory analytical methods and reporting limits.

Parameter	Method	Reference	Reporting Limit
Grain Size	Sieve-pipette method	PSEP, 1986	>2000 to <3.9 microns
Total Organic Carbon	Conversion to CO_2 measured by nondispersive infra-red spectroscopy	PSEP, 1986	1 mg/L
Metals (Partial digestion)	Strong acid (aqua regia) digestion and analyzed via ICP, ICP-MS, or GFAA, depending upon the analyte	- digestion - PSEP, 1996c EPA 3050 - analysis - PSEP, 1996c (EPA 200.7, 200.8, 206.2, 270.2), (SW6010)	1-10 ppm
Metals (Total digestion)	Hydrofluoric acid-based digestion and analyzed via ICP or GFAA, depending upon the analyte	- digestion - PSEP, 1996c EPA 3052 - analysis - PSEP, 1996c (EPA 200.7, 200.8, 206.2, 270.2), (SW6010)	1-10 ppm
Mercury	Cold Vapor Atomic Absorption	PSEP, 1996c EPA 245.5	1-10 ppm
Butyl Tins	Solvent Extraction, Derivitization, Atomic Emission Detector	Manchester Method (Manchester Environmental Laboratory, 1997)	40 µg/kg
Base/Neutral/Acid Organic Compounds	Capillary column Gas Chromatography/ Mass Spectrometry	PSEP 1996d, EPA 8270 & 8081	100-200 ppb
Polynuclear Aromatic Hydrocarbons (PAH)	Capillary column Gas Chromatography/ Mass Spectrometry	PSEP 1996d, extraction following Manchester modification of EPA 8270	100-200 ppb
Chlorinated Pesticides and PCB (Aroclors)	Gas Chromatography Electron Capture Detection	PSEP 1996d, EPA 8081	1-5 ppb
PCB Congeners		NOAA, 1993a, EPA 8081	1-5 ppb

Table 4. Chemistry parameters: Field analytical methods and resolution.

Parameter	Method	Resolution
Temperature	Mercury Thermometer	1.0 °C
Surface salinity	Refractometer	1.0 ppt

Table 5. Benthic infaunal indices calculated to characterize the infaunal invertebrate assemblages identified from each central Puget Sound monitoring station.

Infaunal index	Definition	Calculation
Total Abundance	A measure of density equal to the total number of organisms per sample area	Sum of all organisms counted in each sample
Major Taxa Abundance	A measure of density equal to the total number of organisms in each major taxon group (Annelida, Mollusca, Echinodermata, Arthropoda, miscellaneous taxa) per sample area	Sum of all organisms counted in each major taxon group per sample
Taxa Richness	Total number of taxa (taxa = lowest level of identification for each organism) per sample area	Sum of all taxa identified in each sample
Pielou's Evenness (J') (Pielou, 1966, 1974)	Relates the observed diversity in benthic assemblages as a proportion of the maximum possible diversity for the data set (the equitability (evenness) of the distribution of individuals among species)	$J' = H'/\log s$ Where: $H' = -\sum_{i=1}^{s} p_i \log p_i$ where p_i = the proportion of the assemblage that belongs to the ith species ($p=n_i/N$, where n_I=the number of individuals in the i species and N= total number of individuals), and where s = the total number of species
Swartz's Dominance Index (SDI)(Swartz et al., 1985)	The minimum number of taxa whose combined abundance accounts for 75 percent of the total abundance in each sample	Sum of the minimum number of taxa whose combined abundance accounts for 75 percent of the total abundance in each sample

Table 6. Results of amphipod survival tests for 100 sediment samples from central Puget Sound. Tests performed with *Ampelisca abdita*.

Stratum	Location	Sample	Mean amphipod survival (%)	Mean amphipod survival as % of control	Statistical significance
1	South Port Townsend	106	92	94	*
		107	98	100	
		108	98	100	
2	Port Townsend	109	92	94	
		110	96	98	
		111	88	90	
4	South Admiralty Inlet	112	95	97	
		116	99	101	
		117	94	96	
5	Possession Sound	118	85	93	
		119	94	98	
		120	98	102	
6	Central Basin	121	81	89	
		122	90	99	
		123	78	86	*
7	Port Madison	124	93	106	
		125	89	101	
		126	87	99	
8	West Point	127	91	103	
		128	84	95	
		129	84	95	
		113	94	96	
9	Eagle Harbor	130	85	97	
		131	91	103	
		132	88	100	
10	Central Basin	133	89	98	
		134	90	95	*

Table 6. Continued.

Stratum	Location	Sample	Mean amphipod survival (%)	Mean amphipod survival as % of control	Statistical significance
		135	90	95	
11	Central Basin	136	87	94	
		137	94	101	
		138	99	106	
12	East Passage	139	85	94	
		140	88	98	
		141	72	80	
13	Liberty Bay	142	83	94	
		143	85	97	
		144	81	92	
14	Keyport	145	93	106	
		146	91	103	
		147	87	99	
15	North West Bainbridge	148	87	99	
		149	84	95	
		150	82	93	
16	South West Bainbridge	151	94	99	
		152	94	99	
		153	95	100	
17	Rich Passage	154	93	98	
		155	94	99	
		156	93	98	
18	Port Orchard	157	93	102	
		158	77	85	*
		159	87	92	
19	Sinclair Inlet	160	90	99	
		161	95	104	
		162	79	87	

Table 6. Continued.

Stratum	Location	Sample	Mean amphipod survival (%)	Mean amphipod survival as % of control	Statistical significance
20	Sinclair Inlet	163	85	93	
		164	92	101	
		165	91	100	
21	Port Washington Narrows	166	94	104	
		167	42	47	**
		168	87	97	
22	Dyes Inlet	169	91	101	
		170	90	100	
		171	91	101	
23	Outer Elliott Bay	172	92	102	
		173	96	107	
		174	87	97	
		175	88	98	
24	Shoreline Elliott Bay	176	83	92	
		177	91	101	
		178	91	101	
25	Shoreline Elliott Bay	179	86	96	
		180	91	98	
		181	79	88	*
		115	96	97	
26	Shoreline Elliott Bay	182	91	98	
		183	93	100	
		184	96	103	
27	Mid Elliott Bay	185	97	104	
		186	94	101	
		187	98	108	
		188	96	105	
28	Mid Elliott Bay	189	99	109	
		190	97	107	

Table 6. Continued.

Stratum	Location	Sample	Mean amphipod survival (%)	Mean amphipod survival as % of control	Statistical significance
		191	94	103	
		192	94	103	
29	Mid Elliott Bay	193	92	101	
		194	95	102	
		195	98	105	
		196	93	100	
30	West Harbor Island	197	80	88	
		198	92	101	
		199	82	90	
		114	94	95	
31	East Harbor Island	200	93	100	
		201	84	92	
		202	82	90	*
32	Duwamish	203	94	103	
		204	84	92	
		205	94	101	

*Mean percent survival significantly less than CLIS controls ($p < 0.05$)
**Mean percent survival significantly less than CLIS controls ($p < 0.05$) and less than 80% of CLIS controls

Table 7. Results of sea urchin fertilization tests on pore waters from 100 sediment samples from central Puget Sound. Tests performed with *Strongylocentrotus purpuratus*.

		100% pore water			50% pore water			25% pore water		
Stratum and Location	Sample	Mean % fertilization	% of control	Statistical significance	Mean % fertilization	% of control	Statistical significance	Mean % fertilization	% of control	Statistical significance
1	106	99.8	119		98.8	100		99.6	101	
South Port Townsend	107	98.4	117		99	100		99.4	101	
	108	99.4	118		98.4	99		99.6	101	
2	109	98.2	117		100	101		99	100	
Port Townsend	110	98.2	117		99.4	100		99.4	101	
	111	97	115		98.4	99		97.8	99	
4	116	99.6	118		99.2	100		99	100	
South Admiralty Inlet	117	99.2	118		99.8	101		98.6	100	
	112	94.2	112		96.4	97		99.2	101	
5	118	98.4	117		98.6	99		98.4	100	
Possession Sound	119	99	118		98.6	99		98.8	100	
	120	99.2	118		98.2	99		98.4	100	
6	121	97.2	116		97.6	98		99.6	101	
Central Basin	122	99	118		99	100		97	98	
	123	99.2	118		98.8	100		99.6	101	
7	124	98.8	117		99.2	100		98.4	100	
Port Madison	125	98.4	117		98.6	99		98	99	
	126	98.4	117		99	100		99.2	101	
8	127	99.8	119		99.6	101		99	100	

Table 7. Continued.

Stratum and Location	Sample	100% pore water Mean % fertili-zation	% of control	Stati-stical signifi-cance	50% pore water Mean % fertili-zation	% of control	Stati-stical signifi-cance	25% pore water Mean % fertili-zation	% of control	Stati-stical signifi-cance
West Point	128	99	118		99.4	100		99.6	101	
	129	99.8	119		99.4	100		99.2	101	
	113	99.4	118		99	100		98.4	100	
9	130	99.2	118		98.8	100		99	100	
Eagle Harbor	131	100	119		98.6	99		99	100	
	132	99.6	118		98.8	100		98.4	100	
10	133	98.8	105		99.6	101		98.8	101	
Central Basin	134	99.0	106		99.2	100		99.6	101	
	135	99.4	106		99.6	101		99.4	101	
11	136	100	107		99.6	101		99.6	101	
Central Basin	137	98.8	105		99.4	101		99.6	101	
	138	98.4	105		99	100		98.6	100	
12	139	99.8	107		99.8	101		99.8	102	
East Passage	140	98.8	105		99.6	101		99.8	102	
	141	96	102		97.8	99		98.6	100	
13	142	98.8	105		99	100		99	101	
Liberty Bay	143	99.2	106		98.6	100		99	101	
	144	99.6	106		98.8	100		99.2	101	
14	145	99.4	106		99.4	101		99	101	
Keyport	146	98	105		99.4	101		98.2	100	
	147	99	106		99.2	100		99.4	101	
15	148	99	106		99	100		99.2	101	

Table 7. Continued.

Stratum and Location	Sample	100% pore water Mean % fertili-zation	% of control	Stati-stical signifi-cance	50% pore water Mean % fertili-zation	% of control	Stati-stical signifi-cance	25% pore water Mean % fertili-zation	% of control	Stati-stical signifi-cance
North West Bainbridge	149	97.4	104		99.2	100		99.4	101	
	150	99.2	106		98.6	100		99.2	101	
16	151	99.6	106		99.6	101		99.6	101	
South West Bainbridge	152	98.8	105		97.8	99		99	101	
	153	97.8	104		98.4	100		99.4	101	
17	154	98.2	105		98	99		98.4	100	
Rich Passage	155	99	106		98.6	100		99.6	101	
	156	98.4	105		99.8	101		98.6	100	
18	157	90.6	113		89.4	101		92	105	
Port Orchard	158	90.6	113		94.4	106		92.6	106	
	159	78	97		88.2	99		91	104	
19	160	2	2	**	4.8	5	**	56.6	65	**
Sinclair Inlet	161	83	103		88.6	100		87.4	100	
	162	90.8	113		89.4	101		87.6	100	
20	163	90.8	113		88	99		88.5	101	
Sinclair Inlet	164	90.2	112		91.2	103		88.6	101	
	165	65	81	**	84	95		89.2	102	
21	166	89.4	111		89.2	101		91.6	104	
Port Washington Narrows	167	66.2	82	*	87.2	98		91	104	
	168	55.6	69	**	81.4	92		83	95	
22	169	75.8	94		82.2	93		82.8	94	

Table 7. Continued.

Stratum and Location	Sample	100% pore water: Mean % fertili-zation	100% pore water: % of control	100% pore water: Stati-stical signifi-cance	50% pore water: Mean % fertili-zation	50% pore water: % of control	50% pore water: Stati-stical signifi-cance	25% pore water: Mean % fertili-zation	25% pore water: % of control	25% pore water: Stati-stical signifi-cance
Dyes Inlet	170	81.2	101		77.6	87	++	72	82	*
	171	74	92		79.2	89	+	74.4	85	++
23	172	75.2	94		73.8	83	*	69	79	**
Outer Elliott Bay	173	82	102		75.4	85	++	73.6	84	*
	174	74.8	93		87.4	99		89.4	102	
	175	77	96		86.4	97		87.6	100	
24	176	66	82	*	85.2	96		85	97	
Shoreline Elliott Bay	177	60.6	75	**	77.8	88	++	85.2	97	
	178	85	106		89.6	101		87	99	
25	179	65.4	81	*	77.8	88	++	73.8	84	*
Shoreline Elliott Bay	180	54.4	68	**	73.4	83	*	79.4	91	+
	181	77.4	96		81.4	92		85.8	98	
	115	4.6	6	**	40.8	46	**	64.8	74	**
26	182	66.6	83	*	69.2	78	**	73.4	84	*
Shoreline Elliott Bay	183	70.8	88		77.8	88	++	72.4	83	*
	184	67.8	84	*	78	88	++	73.4	84	*
27	185	96.6	120		93.4	105		94	107	
Mid Elliott Bay	186	93	116		94.6	107		92.8	106	
	187	92.6	115		94.6	107		92.8	106	
	188	92.6	115		93.6	106		96.2	110	
28	189	87.8	109		90.4	102		88.4	101	
Mid Elliott Bay	190	93.8	117		91.2	103		95.8	109	

Table 7. Continued.

Stratum and Location	Sample	100% pore water: Mean % fertilization	100% pore water: % of control	100% pore water: Statistical significance	50% pore water: Mean % fertilization	50% pore water: % of control	50% pore water: Statistical significance	25% pore water: Mean % fertilization	25% pore water: % of control	25% pore water: Statistical significance
	191	90.6	113		88.2	99		92	105	
	192	85.8	107		89.2	101		94.5	108	
29	193	73.6	92		91	103		92.2	105	
Mid Elliott Bay	194	85.4	106		90.4	102		90.4	103	
	195	72.6	90		88	99		90.2	103	
	196	86.6	108		91.2	103		91.2	104	
30	197	50	62	**	78.4	88	++	84	96	
West Harbor Island	198	80.8	100		85	96		87.8	100	
	199	59	73	**	79	89	++	88	100	
	114	69.2	86	+	80.4	91		83.4	95	
31	200	54.8	68	**	85.2	96		90.6	103	
East Harbor Island	201	53.4	66	**	82.6	93		77	88	++
	202	80.6	100		82	92		92	105	
32	203	78.4	98		87	98		92.6	106	
Duwamish	204	82.8	103		86.6	98		89	101	
	205	75.2	94		88	99		86.6	99	

Mean response significantly different from controls (Dunnett's t-test: +=alpha<0.05 or ++=alpha<0.01)

Mean response significantly different from controls (Dunnett's t-test) and exceeds minimum significant difference (*=alpha<0.05 or **=alpha<0.01)

Table 8. Results of Microtox™ tests (as mean mg/ml and percent of Redfish Bay control) and cytochrome P450 HRGS bioassays (as benzo[a]pyrene equivalents) of 100 sediment samples from central Puget Sound.

			Microtox™ EC50				P450 HRGS	
Stratum	Location	Sample	mean (mg/L)	Statistical signifi-cance	% of control	Statistical signifi-cance	B[a]PEq (µg/g)	Statistical signifi-cance
1	South Port Townsend	106	1.37		12.93	**	7.1	
		107	3.07		29.02	**	5.7	
		108	13.30		125.87		4.9	
2	Port Townsend	109	10.67		100.95		1.2	
		110	44.67		422.71		1.2	
		111	17.07		161.51		4.3	
4	South Admiralty Inlet	112	3.13		29.65	**	4.3	
		116	23.57		223.03		0.4	
		117	18.60		176.03		0.6	
5	Possession Sound	118	4.87		46.06	**	9.3	
		119	30.80		291.48		0.7	
		120	23.27		220.19		0.5	
6	Central Basin	121	8.67		82.02		2.1	
		122	2.97		28.08	**	9.0	
		123	5.37		50.79	**	6.1	
7	Port Madison	124	2.80		26.50	**	3.2	
		125	2.97		28.08	**	4.7	
		126	48.70		460.88		2.4	
8	West Point	127	3.73		35.33	**	17.0	++
		128	24.67		233.44		71.1	+++
		129	10.37		98.11		19.1	++
		113	2.90		27.44	**	11.7	++

Table 8. Continued.

Stratum	Location	Sample	Microtox™ EC50 mean (mg/L)	Statistical signifi-cance	% of control	Statistical signifi-cance	P450 HRGS B[a]PEq (μg/g)	Statistical signifi-cance
9	Eagle Harbor	130	1.97		18.61	**	48.3	+++
		131	0.87		8.20	**	96.5	+++
		132	1.77		16.72	**	14.7	++
10	Central Basin	133	12.13		114.83		8.7	
		134	4.60		43.53	**	7.5	
		135	28.63		270.98		13.5	++
11	Central Basin	136	6.30		59.62	**	13.7	++
		137	9.93		94.01		15.7	++
		138	2.43		23.03	**	17.1	++
12	East Passage	139	21.13		200.00		17.8	++
		140	3.63		34.38	**	23.8	++
		141	64.10		606.62		5.8	
13	Liberty Bay	142	5.27		49.84	**	16.7	
		143	1.47		13.88	**	24.8	++
		144	1.17		11.04	**	27.7	++
14	Keyport	145	2.83		26.81	**	2.5	
		146	1.10		10.41	**	32.0	++
		147	5.63		53.31	**	5.6	
15	North West Bainbridge	148	0.94		8.90	**	26.4	++
		149	1.09		10.28	**	6.6	
		150	1.23		11.67	**	9.3	
16	South West Bainbridge	151	0.82		7.76	**	31.6	++
		152	4.60		43.53	**	7.6	
		153	1.97		18.61	**	27.9	++

Table 8. Continued.

Stratum	Location	Sample	Microtox™ EC50 mean (mg/L)	Statistical signifi-cance	% of control	Statistical signifi-cance	P450 HRGS B[a]PEq (μg/g)	Statistical signifi-cance
17	Rich Passage	154	7.80		73.82		1.9	
		155	20.27		191.80		1.6	
		156	30.17		285.49		10.0	
18	Port Orchard	157	3.20		30.28	**	14.1	++
		158	4.70		44.48	**	7.6	
		159	2.27		21.45	**	12.4	++
19	Sinclair Inlet	160	0.81		7.70	**	29.4	++
		161	0.82		7.79	**	44.5	+++
		162	1.63		15.46	**	35.5	++
20	Sinclair Inlet	163	1.02		9.68	**	27.7	++
		164	1.50		14.20	**	64.9	+++
		165	6.83		64.67		39.4	+++
21	Port Washington Narrows	166	3.40		32.18	**	6.5	
		167	3.30		31.23	**	9.9	
		168	0.65		6.12	**	32.3	++
22	Dyes Inlet	169	4.10		38.80	**	3.6	
		170	1.04		9.81	**	27.6	++
		171	2.03		19.24	**	30.4	++
23	Outer Elliott Bay	172	2.13		20.19	**	17.8	++
		173	4.97		47.00	**	19.8	++
		174	35.97		340.38		10.5	
		175	5.23		49.53	**	3.3	
24	Shoreline Elliott Bay	176	2.27		21.45	**	12.5	++
		177	2.57		24.29	**	3.4	
		178	86.83		821.77		10.7	

Table 8. Continued.

Stratum	Location	Sample	Microtox™ EC50 mean (mg/L)	Statistical signifi-cance	% of control	Statistical signifi-cance	P450 HRGS B[a]PEq (µg/g)	Statistical signifi-cance
25	Shoreline Elliott Bay	179	25.10		237.54		38.8	+++
		180	17.50		165.62		34.4	++
		181	17.20		162.78		32.8	++
		115	0.79		7.48	**	144.8	+++
26	Shoreline Elliott Bay	182	26.47		250.47		216.1	+++
		183	3.17		29.97	**	107.2	+++
		184	7.90		74.76		223.2	+++
27	Mid Elliott Bay	185	18.20		172.24		19.7	++
		186	34.00		321.77		54.9	+++
		187	37.73		357.10		26.5	++
		188	67.17		635.65		152.9	+++
28	Mid Elliott Bay	189	9.47		89.59		139.8	+++
		190	5.93		56.15	**	3.6	
		191	179.30		1696.85		29.1	++
		192	35.17		332.81		49.1	+++
29	Mid Elliott Bay	193	50.73		480.13		32.8	++
		194	62.40		590.54		74.1	+++
		195	61.87		585.49		49.3	+++
		196	55.63		526.50		28.6	++
30	West Harbor Island	197	2.23		21.14	**	96.6	+++
		198	59.93		567.19		132.2	+++
		199	64.80		613.25		148.1	+++
		114	0.79		7.48	**	111.4	+++
31	East Harbor Island	200	25.40		240.38		153.5	+++
		201	3.13		29.65	**	135.3	+++

Table 8. Continued.

Stratum	Location	Sample	Microtox™ EC50 mean (mg/L)	Microtox™ EC50 Statistical signifi-cance	Microtox™ EC50 % of control	Microtox™ EC50 Statistical signifi-cance	P450 HRGS B[a]PEq (µg/g)	P450 HRGS Statistical signifi-cance
		202	7.67		72.56		133.2	+++
32	Duwamish	203	3.20		30.28	**	96.9	+++
		204	3.33		31.55	**	77.0	+++
		205	3.57		33.75	**	46.9	+++

Microtox™ EC50 (mg/ml): ^ = mean EC50<0.51 mg/ml determined as the 80% lower prediction limit (LPL) with the lowest (i.e., most toxic) samples removed, but >0.06 mg/ml determined as the 90% lower prediction limit (LPL) earlier in this report.
Microtox™ % of control: * = significantly different from control, ** = significantly different from control ($p < 0.05$) and < 80% of control
Cytochrome P450 HRGS as µg B[a]PEq/g: ++ = value >11.1 benzo[a]pyrene equivalents (µg/g sediment) determined as the 80% upper prediction limit (UPL); +++ = value >37.1 benzo[a]pyrene equivalents (ug/g sediment) determined as the 90% upper prediction limit (UPL)

Table 9. Estimates of the spatial extent of toxicity in four independent tests performed on 100 sediment samples from central Puget Sound. Total study area 731.66 km^2.

Toxicity test/ critical value	"Toxic" area (km^2)	Percent of total area
Amphipod survival		
• Mean survival < 80% of controls	1.0	0.1
Urchin fertilization (mean fertilization < 80% of controls)		
• 100% porewater	5.1	0.7
• 50% porewater	1.5	0.2
• 25% porewater	4.2	0.6
Microbial bioluminescence		
• mean EC50 < 80% of controls	348.9	47.7
• < 0.51 mg/ml[A]	0.0	0.0
• <0.06 mg/ml[B]	0.0	0.0
Cytochrome P450 HRGS		
• > 11.1 µg/g[C]	237.1	32.3
• > 37.1 µg/g[D]	23.7	3.2

[A] Critical value: mean EC50 < 0.51 mg/ml (80% lower prediction limit (LPL) with lowest, i.e. most toxic, samples removed)
[B] Critical value: mean EC50 <0.06 mg/ml (90% LPL of the entire data set - NOAA surveys and northern Puget Sound data, n=1013).
[C] Critical value: > 11.1 µg/g benzo[a]pyrene equivalents/g sediment determined as the 80% upper prediction limit (UPL) following removal of 10% of the most toxic (highest) values from a database composed of NOAA data from many surveys nationwide (n=530).
[D] Critical value: >37.1 µg/g benzo[a]pyrene equivalents/g sediment determined as the 90% UPL of the entire NOAA data set (n=530).

Table 10. Spearman-rank correlation coefficients for combinations of different toxicity tests performed with 100 sediment samples from central Puget Sound.

	Amphipod survival	Signifi-cance (p)	Microbial bioluminescence	Signifi-cance (p)	Cytochrome P450 HRGS assay	Signifi-cance (p)
Amphipod survival*						
Microbial bioluminescence *	0.095	ns				
Cytochrome P450 HRGS	0.099	ns	-0.066	ns		
Urchin fertilization*	0.105	ns	0.116	ns	-0.445	<0.0001

ns = not significant ($p \geq 0.05$)
* analyses performed with control-normalized data

Table 11. Sediment types characterizing the 100 samples collected in 1998 from central Puget Sound.

Sediment type	% Sand	% Silt-clay	% Gravel (range of data for each station type)	No. of stations with this sediment type
Sand	> 80	< 20	0.0 – 5.1	30
Silty sand	60-80	20 - <40	0.0 – 18.6	15
Mixed	20 -< 60	40 – 80	0.0 – 59.2	23
Silt clay	< 20	> 80	0.0 – 1.3	32

Table 12. Samples from 1998 central Puget Sound survey in which individual numerical guidelines were exceeded (excluding Elliott Bay and the Duwamish River).

Stratum, Sample, Location	Number of ERLs exce-eded	Mean ERM Quotient	Number of ERMs exce-eded	Com-pounds exceeding ERMs	Number of SQSs exce-eded	Compounds exceeding SQSs	Number of CSLs exce-eded	Compounds excceding CSLs
1, 106, South Port Townsend		0.07			1	4-Methylphenol	1	4-Methylphenol
1, 107, South Port Townsend	3	0.24			1	4-Methylphenol	1	4-Methylphenol
1, 108, South Port Townsend		0.09			1	4-Methylphenol	1	4-Methylphenol
2, 109, Port Townsend	1	0.08			1	4-Methylphenol	1	4-Methylphenol
2, 110, Port Townsend		0.06						
2, 111, Port Townsend		0.07			1	4-Methylhenol	1	4-Methylphenol
4, 112, South Admiralty Inlet		0.08						
4, 116, South Admiralty Inlet		0.06						
4, 117, South Admiralty Inlet	1	0.06						
5, 118, Possession Sound	3	0.13			1	4-Methylphenol	1	4-Methylphenol
5, 119, Possession Sound		0.06						
5, 120, Possession Sound	1	0.07						
6, 121, Central Basin		0.06						
6, 122, Central Basin	1	0.11			1	4-Methylphenol	1	4-Methylphenol
6, 123, Central Basin	1	0.10			1	4-Methylphenol	1	4-Methylphenol
7, 124, Port Madison		0.07						
7, 125, Port Madison		0.08						
7, 126, Port Madison		0.05						
8, 113, West Point		0.09			1	4-Methylphenol	1	4-Methylphenol
8, 127, West Point		0.14						
8, 128, West Point	16	0.26						
8, 129, West Point	2	0.14						
9, 130, Eagle Harbor	17	0.33						
9, 131, Eagle Harbor	19	0.36						
9, 132, Eagle Harbor	5	0.14						
10, 133, Central Sound		0.07						
10, 134, Central Sound		0.06						
10, 135, Central Sound		0.06						
11, 136, Central Sound	3	0.18						
11, 137, Central Sound	5	0.20						
11, 138, Central Sound	4	0.15						
12, 139, East Passage	2	0.10						
12, 140, East Passage	4	0.13			1	4-Methylphenol	1	4-Methylphenol
12, 141, East Passage		0.06						
13, 142, Liberty Bay	4	0.13						
13, 143, Liberty Bay	4	0.16						

Table 12. Continued.

Stratum, Sample, Location	Number of ERLs exce-eded	Mean ERM Quotient	Number of ERMs exce-eded	Com-pounds exceeding ERMs	Number of SQSs exce-eded	Compounds exceeding SQSs	Number of CSLs exce-eded	Compounds excceding CSLs
13, 144, Liberty Bay	4	0.16						
14, 145, Keyport		0.04						
14, 146, Keyport	4	0.12						
14, 147, Keyport		0.07						
15, 148, NW Bainbridge Island	3	0.12			1	4-Methylphenol	1	4-Methylphenol
15, 149, NW Bainbridge Island		0.04						
15, 150, NW Bainbridge Island		0.07						
16, 151, SW Bainbridge Island	5	0.18			1	Benzyl Alcohol	1	Benzyl Alcohol
16, 152, SW Bainbridge Island		0.08						
16, 153, SW Bainbridge Island	4	0.19						
17, 154, Rich Passage		0.04						
17, 155, Rich Passage		0.04						
17, 156, Rich Passage		0.07						
18, 157, Port Orchard		0.07						
18, 158, Port Orchard		0.05						
18, 159, Port Orchard		0.06						
19, 160, Sinclair Inlet	9	0.35	1	Mercury	1	Mercury	1	Mercury
19, 161, Sinclair Inlet	7	0.27			1	Mercury	1	Mercury
19, 162, Sinclair Inlet	8	0.30	1	Mercury	1	Mercury	1	Mercury
20, 163, Sinclair Inlet	8	0.44	1	Mercury	1	Mercury	1	Mercury
20, 164, Sinclair Inlet	9	0.42	1	Mercury	1	Mercury	1	Mercury
20, 165, Sinclair Inlet	11	0.55	1	Mercury	1	Mercury	1	Mercury
21, 166, Port Washington Narrows		0.06						
21, 167, Port Washington Narrows		0.08						
21, 168, Port Washington Narrows	7	0.17						
22, 169, Dyes Inlet		0.05						
22, 170, Dyes Inlet	10	0.26			1	Benzyl Alcohol		
22, 171, Dyes Inlet	10	0.26			2	Mercury, Benzyl Alcohol	1	Mercury

Table 13. Samples from 1998 central Puget Sound survey in which individual numerical guidelines were exceeded in Elliott Bay and the Duwamish River.

Stratum, Sample, Location	Number of ERLs exce-eded	Mean ERM Quotient	Number of ERMs exce-eded	Compounds exceeding ERMs	Number of SQSs exce-eded	Compounds exceeding SQSs	Number of CSLs exce-eded	Compounds exceeding CSLs
23, 172, Outer Elliott Bay	5	0.20						
23, 173, Outer Elliott Bay	7	0.28						
23, 174, Outer Elliott Bay		0.09			1	Other: Butylbenzyl-phthalate		
23, 175, Outer Elliott Bay		0.07						
24, 176, Shoreline Elliott Bay	5	0.31			4	Metals: Mercury; HPAH**:** Benzo(g,h,i) perylene; LPAH**:** Phenanthrene; Other: Butylbenzyl-phthalate		
24, 177, Shoreline Elliott Bay	2	0.08						
24, 178, Shoreline Elliott Bay		0.14						
25, 115, Shoreline Elliott Bay	24	0.83			2	HPAH: Benzo(g,h,i) perylene; Other: 4-Methylphenol	1	Other: 4-Methylphenol
25, 179, Shoreline Elliott Bay	13	0.52			1	HPAH: Benzo(g,h,i) perylene		
25, 180, Shoreline Elliott Bay	15	0.57			2	HPAH: Benzo(g,h,i) perylene, Indeno(1,2,3-c,d)pyrene		
25, 181, Shoreline Elliott Bay	24	1.59	4	HPAH: Benzo(g,h,i) perylene, Total HPAHs, Total PAH; Other: Total PCBs	1	Metals: Mercury		
26, 182, Shoreline Elliott Bay	24	1.36	5	Metals: Mercury; LPAH: Total LPAHs; HPAH:	4	Metals: Mercury; HPAH: Benzo(g,h,i) perylene, Fluoranthene, Indeno(1,2,3-	1	Metals: Mercury

Table 13. Continued.

Stratum, Sample, Location	Number of ERLs exce-eded	Mean ERM Quotient	Number of ERMs exce-eded	Compounds exceeding ERMs	Number of SQSs exce-eded	Compounds exceeding SQSs	Number of CSLs exce-eded	Compounds exceeding CSLs
				Pyrene, Total HPAH; Other: Total PCBs		c,d)pyrene		
26, 183, Shoreline Elliott Bay	20	0.52			10	HPAH: Benzo(a) anthracene, Benzo(a)pyrene, Benzo(g,h,i) perylene, Indeno(1,2,3-c,d)pyrene, Fluoranthene; Total fluoranthene, Total HPAHs; LPAH: Fluorene, Phenanthrene; Other: Dibenzofuran	1	HPAH: Benzo(a)pyrene
26, 184, Shoreline Elliott Bay	22	1.31	9	HPAH: Benzo(a)anthracene, Benzo(a)pyrene, fluoranthene, Pyrene, Total HPAHs; LPAH: Anthracene, Phenanthrene, Total LPAHs, Total PAHs	7	HPAH: Benzo(a)pyrene, Benzo(g,h,i) perylene, Fluoranthene, Indeno(1,2,3-c,d)pyrene, Total HPAHs, Total fluoranthene; LPAH: Phenanthrene,	4	HPAH: Total Benzofluoranthenes, Fluoranthene, Total HPAHs, Total PAHs
27, 185, Mid Elliott Bay	7	0.39			1	Other: Bis(2-Ethylhexyl) Phthalate		
27, 186, Mid Elliott Bay	13	0.57	1	Metals: Mercury	1	Metals: Mercury	1	Metals: Mercury
27, 187, Mid Elliott Bay	12	0.55						
27, 188, Mid Elliott Bay	23	1.47	6	HPAH: Benzo(a)pyrene, Pyrene, Total HPAHs; LPAH: Phenanthrene Total LPAHs; Other: Total PCBs	6	Metals: Mercury; HPAH: Benzo(g,h,i) perylene, Fluoranthene, Indeno(1,2,3-c,d)pyrene; Other: Benzyl Alcohol, 2,4-Dimethylphenol	2	Metals: Mercury; Other: 2,4-Dimethylphenol
28, 189, Mid Elliott Bay	16	0.43						
28, 190, Mid		0.06			1	Other: Di-N-		

Table 13. Continued.

Stratum, Sample, Location	Number of ERLs exce-eded	Mean ERM Quotient	Number of ERMs exce-eded	Compounds exceeding ERMs	Number of SQSs exce-eded	Compounds exceeding SQSs	Number of CSLs exce-eded	Compounds exceeding CSLs
Elliott Bay						Butylphthalate		
28, 191, Mid Elliott Bay	13	0.45						
28, 192, Mid Elliott Bay	9	0.36						
29, 193, Mid Elliott Bay	9	0.37						
29, 194, Mid Elliott Bay	23	1.05	1	HPAH: Dibenzo(a,h,) anthracene; Other: Total PCBs	3	Metals: Mercury; HPAH: Dibenzo(a,h) anthracene; Other: 4-Methylphenol	2	Metals: Mercury; Other: 4-Methylphenol
29, 195, Mid Elliott Bay	12	0.54						
29, 196, Mid Elliott Bay	13	0.54	1	Metals: Mercury	1	Metals: Mercury	1	Metals: Mercury
30, 114, West Harbor Island	21	1.34	2	HPAH: Benzo(a)pyrene; Other: Total PCBs	2	HPAH: Benzo(g,h,i) perylene; Other: 4-Methylphenol	1	Other: 4-Methylphenol
30, 197, West Harbor Island	18	0.60	2	Metals: Arsenic, Zinc	4	Metals: Arsenic; LPAH: Acenaphthene; Other: Dibenzofuran, 4-Methylphenol	2	Metals: Arsenic; Other: 4-Methylphenol
30, 198, West Harbor Island	22	1.26	6	LPAH: 2-Methylnaphthalene, Acenaphthene, Fluorene, Naphthalene, Total LPAHs; Other: Total PCBs	6	LPAH: Acenaphthene, Fluorene, Naphthalene, Total LPAHs; Other: Dibenzofuran, 4-Methylphenol	4	LPAH: Acenaphthene, Naphthalene; Other: Dibenzofuran, 4-Methylphenol
30, 199, West Harbor Island	22	0.96	2	LPAH: Total LPAHs; Other: Total PCBs	3	LPAH: Acenaphthene, Dibenzofuran; Other: 4-Methylphenol	1	Other: 4-Methylphenol
31, 200, East Harbor Island	22	3.93	1	Other: Total PCBs	2	Other: 1,4-Dichlorobenzene, 4-Methylphenol	1	Other: 4-Methylphenol
31, 201, East Harbor Island	23	1.60	1	Other: Total PCBs	2	Other: Bis(2-Ethylhexyl) Phthalate, 4-Methylphenol	1	Other: 4-Methylphenol
31, 202, East Harbor Island	25	2.16	1	Other: Total PCBs	1	Other: 4-Methylphenol	1	Other: 4-Methylphenol
32, 203,	13	0.67						Other: 4-

Table 13. Continued.

Stratum, Sample, Location	Number of ERLs exce-eded	Mean ERM Quotient	Number of ERMs exce-eded	Compounds exceeding ERMs	Number of SQSs exce-eded	Compounds exceeding SQSs	Number of CSLs exce-eded	Compounds exceeding CSLs
Duwamish								Methylphenol
32, 204, Duwamish	8	0.72	1	Other: Total PCBs	2	Other: Bis(2-Ethylhexyl) Phthalate, 4-Methylphenol	1	Other: 4-Methylphenol
32, 205, Duwamish	20	2.01	1	Other: Total PCBs	5	HPAH: Benzo(g,h,i) perylene, Indeno(1,2,3-c,d)pyrene; Other: Butylbenzyl-phthalate, 4-Methylphenol, Pentachlorophenol	1	Other: 4-Methylphenol

Table 14. Number of 1998 central Puget Sound samples exceeding individual numerical guidelines and estimated spatial extent of chemical contamination (expressed as percentage of total area) relative to each guideline. Total sampling area = 731.66 km^2.

Compound	$\geq$ ERM[a]			> SQS[b]			> CSL[b]		
	No.	% of Total Area	Sample Number and Location	No.	% of Total Area	Sample Number and Location	No.	% of Total Area	Sample Number and Location
Trace metals[c]									
Arsenic	1	0.04	W. Harbor Isl.: 197	1	0.04	W. Harbor Isl.: 197	1	0.04	W. Harbor Isl.: 197
Cadmium	0	0		0	0		0	0	
Chromium	0	0		0	0		0	0	
Copper	0	0		0	0		0	0	
Lead	0	0		0	0		0	0	
Mercury	9	1.11	Sinclair Inlet: 160, 162, 163, 164, 165; Elliott Bay: 182, 186, 188, 196	14	1.98	Sinclair Inlet: 160, 161, 162, 163, 164, 165; Dyes Inlet: 171; Elliott Bay: 176, 181, 182, 186, 188, 194, 196	12	1.88	Sinclair Inlet : 160, 161, 162, 163, 164, 165; Dyes Inlet: 171; Elliott Bay: 182, 186, 188, 194, 196
Nickel	4	1.31	Liberty Bay: 142, 144; Bainbridge Isl.: 148; Dyes Inlet: 170	NA	NA		NA	NA	
Silver	0	0		0	0		0	0	
Zinc	1	0.04	W. Harbor Isl.: 197	0	0		0	0	
Total for any individual trace metals (excluding Nickel)	10	2.46	Sinclair Inlet: 160, 162, 163, 164, 165; Elliott Bay: 182, 186, 188, 196; W. Harbor Isl.: 197	15	2.02	Sinclair Inlet: 160, 161, 162, 163, 164, 165; Dyes Inlet: 171; Elliott Bay: 176, 181, 182, 186, 188, 194, 196; W. Harbor Isl.: 197	13	1.91	Sinclair Inlet: 160, 161, 162, 163, 164, 165; Dyes Inlet: 171; Elliott Bay: 182, 186, 188, 194, 196; W. Harbor Isl.: 197
Organic Compounds									
LPAH									
2-Methylnaphthalene	1	0.04	W. Harbor Isl.: 198	1	0.04	W. Harbor Isl.: 198	1	0.04	W. Harbor Isl.: 198
Acenaphthene	1	0.04	W. Harbor Isl.: 198	3	0.11	W. Harbor Isl.:197, 198, 199	1	0.04	W. Harbor Isl.: 198
Acenaphthylene	0	0		0	0		0	0	
Anthracene	1	0.02	Elliott Bay: 184	0	0		0	0	
Fluorene	1	0.04	W. Harbor Isl.: 198	2	0.05	Elliott Bay: 183; W. Harbor Isl.: 198	0	0	
Naphthalene	1	0.04	W. Harbor Isl.: 198	1	0.04	W. Harbor Isl.: 198	1	0.04	W. Harbor Isl.: 198

Table 14. Continued.

Compound	≥ ERM[a] No.	≥ ERM[a] % of Total Area	≥ ERM[a] Sample Number and Location	> SQS[b] No.	> SQS[b] % of Total Area	> SQS[b] Sample Number and Location	> CSL[b] No.	> CSL[b] % of Total Area	> CSL[b] Sample Number and Location
Phenanthrene	2	0.16	Elliott Bay: 184, 188	3	0.09	Elliott Bay: 176, 183, 184,	0	0	
Total for any individual LPAH	3	0.19	Elliott Bay: 184, 188; W. Harbor Isl.: 198	6	0.2	Elliott Bay: 176, 183, 184; W. Harbor Isl.: 197, 198, 199	1	0.04	W. Harbor Isl.: 198
Sum of LPAHs:									
Sum of 6 LPAH[d] (WA Ch. 173-204 RCW)	NA	NA		1	0.36	W. Harbor Isl.: 198	0	0	
Sum of 7 LPAH (Long et al., 1995)	5	0.25	Elliott Bay: 182, 184, 188; W. Harbor Isl.: 198, 199	NA	NA		NA	NA	
<u>HPAH</u>									
Benzo(a)anthracene	1	0.02	Elliott Bay: 184	1	0.02	Elliott Bay: 183	0	0	
Benzo(a)pyrene	3	0.19	W. Harbor Isl.: 114; Elliott Bay: 184, 188	3	0.08	Elliott Bay: 115, 183, 184	1	0.02	Elliott Bay: 183
Benzo(g,h,i)perylene	NA	NA		11	0.50	W. Harbor Isl.: 114; Elliott Bay: 115, 176, 179, 180, 181, 182, 183, 184, 188; Duwamish: 205	0	0	
Chrysene	0	0		0	0		0	0	
Dibenzo(a,h)anthracene	1	0.1	Elliott Bay: 194	1	0.1	Elliott Bay: 194	0	0	
Fluoranthene	1	0.02	Elliott Bay: 184	4	0.19	Elliott Bay: 182, 183, 184, 188	1	0.02	Elliott Bay: 184
Indeno(1,2,3-c,d)pyrene	NA	NA	Elliott Bay: 182, 184, 188	5	0.12	Elliott Bay: 180, 182, 183, 184; Duwamish: 205	0	0	
Pyrene	3	0.17	Elliott Bay: 182, 184, 188	0	0		0	0	
Total Benzofluoranthenes	NA	NA		2	0.03	Elliott Bay: 183, 184	1	0.02	Elliott Bay: 184
Total for any individual HPAH	5	0.31	W. Harbor Isl.: 114; Elliott Bay: 182, 184, 188, 194	12	0.60	W. Harbor Isl.: 114; Elliott Bay: 115, 176, 179, 180, 181, 182, 183, 184, 188, 194; Duwamish: 205	2	0.03	Elliott Bay: 183, 184

Table 14. Continued.

Compound	≥ ERM[a] No.	≥ ERM[a] % of Total Area	≥ ERM[a] Sample Number and Location	> SQS[b] No.	> SQS[b] % of Total Area	> SQS[b] Sample Number and Location	> CSL[b] No.	> CSL[b] % of Total Area	> CSL[b] Sample Number and Location
Sum of HPAHs:									
Sum of 9 HPAH (WA Ch. 173-204 RCW)	NA	NA		2	0.73	Elliott Bay: 183, 184	0	0	
Sum of 6 HPAH (Long et al., 1995)	3	0.17	Elliott Bay: 182, 184, 188	NA	NA		NA	NA	
Total for any individual PAH	6	0.35	W. Harbor Isl.: 114, 198; Elliott Bay: 182, 184, 188, 194	15	0.71	Elliott Bay: 115, 176, 179, 180, 181, 182, 183, 184, 188, 194; W. Harbor Isl.: 114, 197, 198, 199; Duwamish: 205	3	0.07	Elliott Bay: 183, 184; W. Harbor Isl.: 198
Sum of 13 PAHs (Long et al., 1995)	1	0.02	Elliott Bay: 184	NA	NA		NA	NA	
Phenols									
2,4-Dimethylphenol	NA	NA		1	0.14	Elliott Bay: 188	1	0.14	Elliott Bay: 188
2-Methylphenol	NA	NA		0	0		0	0	
4-Methylphenol	NA	NA		22	23		22	23	
Pentachlorophenol	NA	NA		1	0.03	Duwamish: 205	0	0	
Phenol	NA	NA		0	0		0	0	
Total for any individual phenols:	NA	NA		23	23.2		23	23.2	
Phthalate Esters									
Bis (2-Ethylhexyl) Phthalate	NA	NA		4	0.24	Elliott Bay: 185; E. Harbor Isl.: 201; Duwamish: 204, 205	1	0.03	Duwamish: 205
>QL only				3	0.2	Elliott Bay: 185; E. Harbor Isl.: 201; Duwamish: 204	0	0	
Butylbenzylphthalate	NA	NA		3	0.47	Elliott Bay: 174, 176; Duwamish: 205	0	0	
Diethylphthalate	NA	NA		0	0		0	0	
Dimethylphthalate	NA	NA		0	0		0	0	
Di-N-Butyl Phthalate	NA	NA		1	0.1	Elliott Bay: 190	0	0	
Di-N-Octyl Phthalate	NA	NA		0	0		0	0	
Total for any individual phthalate esters	NA	NA		7	0.76	Elliott Bay: 174, 176, 185, 190; E. Harbor Isl.: 201; Duwamish: 204, 205	1	0.03	Duwamish: 205

Table 14. Continued.

Compound	≥ ERM[a] No.	≥ ERM[a] % of Total Area	≥ ERM[a] Sample Number and Location	> SQS[b] No.	> SQS[b] % of Total Area	> SQS[b] Sample Number and Location	> CSL[b] No.	> CSL[b] % of Total Area	> CSL[b] Sample Number and Location
Chlorinated Pesticide and PCBs									
4,4'-DDE	0	0		NA	NA		NA	NA	
Total DDT	0	0		NA	NA		NA	NA	
Total PCB:									
Total Aroclors (WA Ch. 173-204 RCW)	NA	NA		36	38.2		1	0.02	E. Harbor Isl.: 200
>QL only				0	0		0	0	
Total congeners (Long et al., 1995):	13	0.59	Elliott Bay: 181, 182, 188, 194; W. Harbor Isl.: 114,198, 199; E. Harbor Isl.: 200, 201, 202; Duwamish: 203, 204, 205	NA	NA		NA	NA	
>QL only	12	0.55	Elliott Bay: 181, 182, 188, 194; W. Harbor Isl.: 114,198, 199; E. Harbor Isl.: 200, 201, 202; Duwamish: 204, 205						
Miscellaneous Compounds									
1,2-Dichlorobenzene	NA	NA		10	21.1	Pt. Townsend: 110; S. Admiralty Inlet: 116, 117; Central Basin: 121; Rich Passage: 154, 155, 174; Elliott Bay: 177,178, 190	10	21.1	Pt. Townsend: 110; S. Admiralty Inlet: 116, 117; Central Basin: 121; Rich Passage: 154, 155, 174; Elliott Bay: 177,178, 190
>QL only				0	0		0	0	
1,2,4-Trichlorobenzene	NA	NA		42	49.8		15	36.4	
>QL only				0	0		0	0	
1,4-Dichlorobenzene	NA	NA		4	1.35	Pt. Townsend: 110; Elliott Bay: 174, 177; E. Harbor Isl.: 200	0	0	
>QL only				1	0.02	E. Harbor Isl.: 200	0	0	
Benzoic Acid	NA	NA		97	83.5		97	83.5	
>QL only				89	81.5		89	81.5	

Table 14. Continued.

Compound	≥ ERM[a]			> SQS[b]			> CSL[b]		
	No.	% of Total Area	Sample Number and Location	No.	% of Total Area	Sample Number and Location	No.	% of Total Area	Sample Number and Location
Benzyl Alcohol	NA	NA		5	1.76	Liberty Bay: 144; Bainbridge Isl.: 151; Dyes Inlet: 170, 171; Elliott Bay: 188	1	0.47	Bainbridge Isl.:151
>QL only				4	1.67	Bainbridge Isl.: 151; Dyes Inlet: 170, 171; Elliott Bay: 188	1	0.47	Bainbridge Isl.:151
Dibenzofuran	NA	NA		4	0.13	Elliott Bay: 183; W. Harbor Isl.: 197, 198, 199	1	0.04	W. Harbor Isl.: 198
Hexachlorobenzene	NA	NA		6	7.82	Pt. Townsend: 110; Central Basin: 121; Pt. Madison: 126; Central Sound: 134; Rich Passage: 154, 155	0	0	
>QL only				0	0		0	0	
Hexachlorobutadiene	NA	NA		1	0.89	Pt. Townsend: 110	0	0	
>QL only				0	0		0	0	
N-Nitrosodiphenylamine	NA	NA		0	0		0	0	
***Total for all individual compounds (excluding Nickel)**	22	1.6		99	99.9		99	99.9	
>QL only	21	1.6		95	99.6		94	99.4	
***Total for all individual compounds (excluding Nickel and Benzoic Acid)**				79	77.2		50	60.9	
>QL only				44	26.1		36	24.8	

[a] ERM = effects range median (Long et al., 1995)
[b] SQS = sediment quality standard, CSL = cleanup screening levels (Washington State Sediment Management Standards - Ch. 173-204 WAC)
[c] Trace metal data derived with strong acid digestion were used for comparison to ERM values while those derived with hydrofluoric acid digestion were used for comparison to SQS and CSL values
[d]The LPAH criterion represents the sum of the Naphthalene, Acenaphthylene, Acenaphthene, Fluorene, Phenanthrene, and Anthracene values
* = calculation includes all values which exceed guidelines or standards, **including** those that were at or below the quantitation limits reported by Manchester Environmental Lab
>QL only = calculation includes all values which exceed guidelines or standards, **excluding** those that were at or below the quantitation limits reported by Manchester Environmental Lab
NA = no guideline or standard available

Table 15. Spearman-rank correlation coefficients (rho, corrected for ties) and significance levels (p) for results of four toxicity tests and concentrations of trace metals, chlorinated organic hydrocarbons, and total PAHs, normalized to their respective ERM, SQS, CSL values for all 1998 central Puget Sound sites (n=100).

Chemical	Amphipod survival	(p)	Urchin fertilization	(p)	Microbial bioluminescence	(p)	Cytochrome P-450	(p)
ERM values								
mean ERM quotients for 9 trace metals	0.068	ns	-0.267	ns	-0.165	ns	0.726	****
mean ERM quotients for 3 chlorinated organic hydrocarbons	0.172	ns	-0.576	****	0.09	ns	0.844	****
mean ERM quotients for 13 polynuclear aromatic hydrocarbons	0.092	ns	-0.5	****	-0.01	ns	0.928	****
mean ERM quotients for 25 substances	0.12	ns	-0.518	****	0.03	ns	0.901	****
SQS values								
mean SQS quotients for 8 trace metals	0.056	ns	-0.319	*	-0.221	ns	0.8	****
mean SQS quotients for 6 low molecular weight polynuclear aromatic hydrocarbons	0.087	ns	-0.559	****	0.37	**	0.573	****
mean SQS quotients for 9 high molecular weight polynuclear aromatic hydrocarbons	0.089	ns	-0.656	****	0.138	ns	0.735	****
mean SQS quotients for 15 polynuclear aromatic hydrocarbons	0.089	ns	-0.656	****	0.194	ns	0.719	****
CSL values								
mean CSL quotients for 8 trace metals	0.058	ns	-0.316	*	-0.225	ns	0.798	****
mean CSL quotients for 6 low molecular weight polynuclear aromatic hydrocarbons	0.09	ns	-0.539	****	0.371	**	0.575	****
mean CSL quotients for 9 high molecular weight polynuclear aromatic hydrocarbons	0.087	ns	-0.662	****	0.129	ns	0.737	****
mean CSL quotients for 15 polynuclear aromatic hydrocarbons	0.091	ns	-0.656	****	0.193	ns	0.724	****

ns = $p > 0.05$
* = $p \leq 0.05$
** = $p \leq 0.01$
*** = $p \leq 0.001$
**** = $p \leq 0.0001$

Table 16. Spearman-rank correlation coefficients (rho, corrected for ties) and significance levels (p) for results of four toxicity tests and concentrations of partial digestion metals in sediments for all 1998 central Puget Sound sites (n=100).

Chemical	Amphipod survival	(p)	Urchin fertilization	(p)	Microbial bioluminescence	(p)	Cytochrome P450 HRGS	(p)
Aluminum	0.055	ns	0.101	ns	-0.267	ns	0.522	****
Antimony	-0.346	ns	0.113	ns	-0.103	ns	0.158	ns
Arsenic	0.072	ns	-0.297	ns	-0.135	ns	0.792	****
Barium	0.087	ns	-0.207	ns	0.005	ns	0.719	****
Beryllium	-0.059	ns	0.072	ns	-0.104	ns	0.502	****
Cadmium	0.023	ns	0.017	ns	-0.593	****	0.279	ns
Calcium	-0.134	ns	0.131	ns	-0.39	*	0.276	ns
Chromium	-0.037	ns	0.117	ns	-0.338	ns	0.453	***
Cobalt	-0.04	ns	0.151	ns	0.016	ns	0.372	*
Copper	0.044	ns	-0.317	ns	-0.251	ns	0.828	****
Iron	0.004	ns	0.098	ns	-0.174	ns	0.475	****
Lead	0.082	ns	-0.45	***	-0.147	ns	0.883	****
Magnesium	0.025	ns	0.314	ns	-0.292	ns	0.256	ns
Manganese	-0.06	ns	0.192	ns	0.142	ns	0.249	ns
Mercury	0.125	ns	-0.383	*	-0.175	ns	0.794	****
Nickel	-0.023	ns	0.365	*	-0.283	ns	0.12	ns
Potassium	0.021	ns	0.15	ns	-0.262	ns	0.456	***
Selenium	-0.045	ns	0.192	ns	-0.527	*	-0.2	ns
Silver	0.04	ns	-0.21	ns	-0.115	ns	0.651	****
Sodium	0.029	ns	0.116	ns	-0.332	ns	0.473	***
Thallium	-0.091	ns	-0.206	ns	-0.16	ns	-0.086	ns
Titanium	0.013	ns	0.081	ns	-0.341	ns	0.504	****
Vanadium	0.03	ns	-0.019	ns	-0.149	ns	0.59	****
Zinc	0.001	ns	-0.226	ns	-0.27	ns	0.744	****

ns = $p > 0.05$
* = $p \leq 0.05$
** = $p \leq 0.01$
*** = $p \leq 0.001$
**** = $p \leq 0.0001$

Table 17. Spearman-rank correlation coefficients (rho, corrected for ties) and significance levels (p) for results of four toxicity tests and concentrations of total digestion metals in sediments for all 1998 central Puget Sound sites (n=100).

Chemical	Amphipod survival	(p)	Urchin fertilization	(p)	Microbial bioluminescence	(p)	Cytochrome P450 HRGS	(p)
Aluminum	0.115	ns	-0.144	ns	0.248	ns	0.438	***
Antimony	0.109	ns	-0.337	ns	0.084	ns	0.618	****
Arsenic	0.076	ns	-0.344	ns	-0.089	ns	0.807	****
Barium	0.032	ns	0.055	ns	0.37	*	0.03	ns
Beryllium	0.056	ns	-0.201	ns	0.322	ns	0.407	**
Cadmium	0.03	ns	-0.272	ns	-0.055	ns	0.431	*
Calcium	0.024	ns	-0.279	ns	0.219	ns	0.36	*
Chromium	-0.087	ns	0.068	ns	-0.284	ns	0.234	ns
Cobalt	-0.028	ns	-0.142	ns	0.139	ns	0.526	****
Copper	0.056	ns	-0.332	ns	-0.185	ns	0.792	****
Iron	0.008	ns	-0.229	ns	0.029	ns	0.605	****
Lead	0.024	ns	-0.414	**	-0.191	ns	0.837	****
Magnesium	0.055	ns	0.013	ns	-0.03	ns	0.468	***
Manganese	-0.119	ns	-0.172	ns	0.388	*	0.238	ns
Nickel	0.019	ns	0.192	ns	-0.242	ns	0.282	ns
Potassium	-0.013	ns	0.013	ns	0.075	ns	0.411	**
Selenium	0.052	ns	-0.075	ns	-0.279	ns	0.287	ns
Silver	0.5	ns	0.5	ns	-0.5	ns	0.5	ns
Sodium	0.075	ns	0.12	ns	-0.193	ns	0.356	*
Thallium	0.114	ns	-0.203	ns	-0.101	ns	0.068	ns
Titanium	0.006	ns	-0.298	ns	-0.004	ns	0.59	****
Vanadium	0.024	ns	-0.168	ns	-0.046	ns	0.498	****
Zinc	0.051	ns	-0.324	ns	-0.162	ns	0.757	****
Silicon	-0.041	ns	-0.077	ns	0.344	ns	-0.464	***
Tin	0.097	ns	-0.476	***	-0.08	ns	0.858	****

ns = $p > 0.05$
* = $p \leq 0.05$
** = $p \leq 0.01$
*** = $p \leq 0.001$
**** = $p \leq 0.0001$

Table 18. Spearman-rank correlation coefficients (rho, corrected for ties) and significance levels (p) for results of four toxicity tests and concentrations of Low Molecular Weight Polynuclear Aromatic Hydrocarbons (LPAH) in sediments for all 1998 central Puget Sound sites (n=100).

Chemical	Amphipod survival	(p)	Urchin fertilization	(p)	Microbial bioluminescence	(p)	Cytochrome P450 HRGS	(p)
1,6,7-Trimethylnaphthalene	0.124	ns	-0.383	*	0.043	ns	0.769	****
1-Methylnaphthalene	0.103	ns	-0.329	ns	0.078	ns	0.761	****
1-Methylphenanthrene	0.031	ns	-0.45	***	0.015	ns	0.879	****
2,6-Dimethylnaphthalene	0.03	ns	-0.166	ns	-0.372	*	0.642	****
2-Methylnaphthalene	0.113	ns	-0.346	ns	0.115	ns	0.792	****
2-Methylphenanthrene	0.042	ns	-0.386	*	0.002	ns	0.845	****
Acenaphthene	0.129	ns	-0.52	****	0.06	ns	0.883	****
Acenaphthylene	0.102	ns	-0.48	****	0.01	ns	0.897	****
Anthracene	0.107	ns	-0.508	****	-0.016	ns	0.904	****
Biphenyl	0.167	ns	-0.436	**	0.084	ns	0.783	****
Dibenzothiophene	0.165	ns	-0.488	***	0.143	ns	0.876	****
Fluorene	0.124	ns	-0.45	***	0.072	ns	0.879	****
Naphthalene	0.183	ns	-0.366	ns	0.2	ns	0.799	****
Phenanthrene	0.077	ns	-0.468	***	0.025	ns	0.863	****
Retene	0.106	ns	-0.426	**	-0.014	ns	0.812	****
Sum of 6 LPAH^	0.08	ns	-0.555	****	0.352	ns	0.579	****
Sum of 7 LPAH^^	0.101	ns	-0.466	***	0.046	ns	0.897	****
Total LPAH	0.106	ns	-0.465	***	0.017	ns	0.909	****

^6 LPAH = defined by WA Ch. 173-204 RCW; Acenaphthene, Acenaphthylene, Anthracene, Fluorene, Naphthalene, Phenanthrene, carbon normalized.
^^7LPAH = defined by Long et al., 1995; Acenaphthene, Acenaphthylene, Anthracene, Fluorene, 2-Methylnaphthalene, Naphthalene, Phenanthrene
ns = p > 0.05
* = p ≤ 0.05
** = p ≤ 0.01
*** = p ≤ 0.001
**** = p ≤ 0.0001

Table 19. Spearman-rank correlation coefficients (rho, corrected for ties) and significance levels (p) for results of four toxicity tests and concentrations of High Molecular Weight Polynuclear Aromatic Hydrocarbons (HPAH) in sediments for all 1998 central Puget Sound sites (n=100).

Chemical	Amphipod survival	(p)	Urchin fertilization	(p)	Microbial bioluminescence	(p)	Cytochrome P450 HRGS	(p)
Benzo(a)anthracene	0.078	ns	-0.499	****	-0.074	ns	0.934	****
Benzo(a)pyrene	0.081	ns	-0.529	****	-0.089	ns	0.926	****
Benzo(b)fluoranthene	0.084	ns	-0.51	****	-0.083	ns	0.944	****
Benzo(e)pyrene	0.099	ns	-0.512	****	-0.114	ns	0.941	****
Benzo(g,h,i)perylene	0.087	ns	-0.53	****	-0.091	ns	0.936	****
Benzo(k)fluoranthene	0.091	ns	-0.503	****	-0.104	ns	0.946	****
Chrysene	0.069	ns	-0.502	****	-0.085	ns	0.931	****
Dibenzo(a,h)anthracene	0.112	ns	-0.504	****	-0.031	ns	0.932	****
Fluoranthene	0.072	ns	-0.479	****	-0.071	ns	0.917	****
Indeno(1,2,3-c,d)pyrene	0.09	ns	-0.523	****	-0.098	ns	0.939	****
Perylene	0.089	ns	-0.413	**	-0.033	ns	0.863	****
Pyrene	0.108	ns	-0.472	***	-0.014	ns	0.902	****
sum of 6 HPAH^	0.086	ns	-0.501	****	-0.067	ns	0.932	****
sum of 9 HPAH^^	0.082	ns	-0.632	****	0.148	ns	0.728	****
Total HPAH	0.079	ns	-0.506	****	-0.075	ns	0.938	****
sum of 13 PAH^^^	0.098	ns	-0.498	****	-0.028	ns	0.93	****
Sum of 15 PAH^^^^	0.085	ns	-0.632	****	0.188	ns	0.718	****
Total all PAH	0.09	ns	-0.503	****	-0.045	ns	0.935	****

^6HPAH = defined by Long et al., 1995; Benzo(a)anthracene, Benzo(a)pyrene, Chrysene, Dibenzo(a,h)anthracene, Fluoranthene, Pyrene
^^9HPAH = defined by WA Ch. 173-204 RCW; Benzo(a)anthracene, Benzo(a)pyrene, Benzo(1,2,3,-c,d)pyrene, Benzo(g,h,I)perylene, Chrysene, Dibenzo(a,h)anthracene, Fluoranthene, Pyrene, Total Benzofluranthenes, carbon normalized
^^^13PAH = 7LPAH and 6HPAH
^^^^15PAH= 6LPAH and A11HPAH
ns = $p > 0.05$
* = $p \leq 0.05$
** = $p \leq 0.01$
*** = $p \leq 0.001$
**** = $p \leq 0.0001$

Table 20. Spearman-rank correlation coefficients (rho, corrected for ties) and significance levels (p) for results of four toxicity tests and concentrations of organotins and organic compounds in sediments for all 1998 central Puget Sound sites (n=100).

Chemical	Amphipod survival	(p)	Urchin fertilization	(p)	Microbial bioluminescence	(p)	Cytochrome P450 HRGS	(p)
Organotins								
Dibutyltin Dichloride	-0.058	ns	-0.584	****	0.117	ns	0.764	****
Tributyltin Chloride	0.055	ns	-0.617	****	0.159	ns	0.875	****
Phenols								
2,4-Dimethylphenol	0.36	ns	0.049	ns	0.279	ns	0.676	ns
2-Methylphenol	-0.023	ns	-0.006	ns	-0.392	ns	0.433	ns
4-Methylphenol	-0.049	ns	-0.033	ns	-0.036	ns	0.32	ns
Pentachlorophenol	0.339	ns	0.009	ns	-0.193	ns	0.293	ns
Phenol	0.15	ns	0.404	ns	-0.264	ns	0.314	ns
Miscellaneous								
1,2-Dichlorobenzene	-0.8	ns	-0.2	ns	0.8	ns	-0.6	ns
1,4-Dichlorobenzene	-0.186	ns	-0.363	ns	-0.018	ns	0.502	ns
Benzoic Acid	0.067	ns	0.179	ns	-0.572	****	0.238	ns
Benzyl Alcohol	0.365	ns	0.178	ns	-0.097	ns	0.476	ns
Bis(2-Ethylhexyl) Phthalate	-0.215	ns	0.196	ns	-0.334	ns	0.177	ns
Butylbenzylphthalate	-0.214	ns	-0.313	ns	-0.296	ns	0.596	ns
Dibenzofuran	0.196	ns	-0.417	**	0.066	ns	0.867	****
Diethylphthalate	0.433	ns	0.046	ns	0.07	ns	0.212	ns
Dimethylphthalate	0.112	ns	0.399	ns	0.14	ns	-0.587	ns
Di-N-Butylphthalate	0.509	ns	0.102	ns	0.138	ns	0.172	ns
Hexachlorobenzene	-0.031	ns	0.162	ns	-0.323	ns	0.038	ns
N-Nitrosodiphenylamine	0	ns	0.211	ns	0.4	ns	0.4	ns

ns = $p > 0.05$
* = $p \leq 0.05$
** = $p \leq 0.01$
*** = $p \leq 0.001$
**** = $p \leq 0.0001$

Table 21. Spearman-rank correlation coefficients (rho, corrected for ties) and significance levels (p) for results of four toxicity tests and concentrations of DDT and PCB compounds in sediments for all 1998 central Puget Sound sites (n=100).

Chemical	Amphipod survival	(p)	Urchin fertilization	(p)	Microbial bioluminescence	(p)	Cytochrome P450 HRGS	(p)
4,4'-DDD	-0.332	ns	-0.421	ns	-0.067	ns	0.552	ns
4,4'-DDE	-0.298	ns	-0.357	ns	0.075	ns	0.643	**
Total DDT	-0.214	ns	-0.484	ns	0.122	ns	0.697	****
PCB Aroclor 1242	-0.18	ns	-0.286	ns	-0.464	ns	-0.036	ns
PCB Aroclor 1254	-0.126	ns	-0.625	***	0.24	ns	0.784	***
PCB Aroclor 1260	0.042	ns	-0.544	**	0.207	ns	0.743	****
Total PCB Aroclor	-0.049	ns	-0.606	****	0.459	*	0.639	****
PCB Congener 8	-0.314	ns	0.086	ns	-0.6	ns	0.143	ns
PCB Congener 18	-0.216	ns	-0.357	ns	0.072	ns	0.624	*
PCB Congener 28	-0.155	ns	-0.532	*	0.246	ns	0.737	****
PCB Congener 44	-0.118	ns	-0.422	ns	0.301	ns	0.648	***
PCB Congener 52	-0.073	ns	-0.539	**	0.273	ns	0.71	****
PCB Congener 66	0.015	ns	-0.516	**	0.199	ns	0.701	****
PCB Congener 101	0.08	ns	-0.514	**	0.183	ns	0.833	****
PCB Congener 105	0.091	ns	-0.488	*	0.355	ns	0.712	****
PCB Congener 118	0.02	ns	-0.468	**	0.141	ns	0.726	****
PCB Congener 128	-0.129	ns	-0.519	**	0.099	ns	0.702	****
PCB Congener 138	0.082	ns	-0.484	*	0.351	ns	0.748	****
PCB Congener 153	0.098	ns	-0.449	*	0.195	ns	0.828	****
PCB Congener 170	-0.053	ns	-0.512	**	0.203	ns	0.75	****
PCB Congener 180	-0.01	ns	-0.488	*	0.275	*	0.752	****
PCB Congener 187	-0.217	ns	-0.39	ns	0.066	ns	0.619	***
PCB Congener 195	-0.195	ns	-0.31	ns	-0.06	ns	0.562	ns
PCB Congener 206	-0.173	ns	-0.293	ns	-0.167	ns	0.618	***
Total PCB Congeners	0.029	ns	-0.43	*	0.193	ns	0.828	****

ns = $p > 0.05$
* = $p \leq 0.05$
** = $p \leq 0.01$
*** = $p \leq 0.001$
**** = $p \leq 0.0001$

Table 22. Total abundance, major taxa abundance, and major taxa percent abundance for the 1998 central Puget Sound sampling stations.

Stratum	Sample	Total Abundance	Annelida	Annelida % of total abundance	Arthropoda	Arthropoda % of total abundance	Mollusca	Mollusca % of total abundance	Echino-dermata	Echinodermata % of total abundance	Misc. Taxa	Misc. Taxa % of total abundance
1	106	302	149	49%	47	16%	95	31%	8	3%	3	1%
South Port	107	580	292	50%	66	11%	218	38%	3	1%	1	0%
Townsend	108	707	99	14%	73	10%	106	15%	421	60%	8	1%
2	109	702	333	47%	181	26%	161	23%	3	0%	24	3%
Port	110	410	96	23%	67	16%	224	55%	17	4%	6	1%
Townsend	111	807	479	59%	42	5%	268	33%	7	1%	11	1%
4	112	2325	758	33%	1349	58%	133	6%	26	1%	59	3%
South	116	554	95	17%	197	36%	254	46%	3	1%	5	1%
Admiralty	117	227	78	34%	60	26%	84	37%	0	0%	5	2%
5	118	110	67	61%	14	13%	19	17%	4	4%	6	5%
Possession	119	197	86	44%	85	43%	17	9%	1	1%	8	4%
Sound	120	201	92	46%	80	40%	29	14%	0	0%	0	0%
6	121	1272	107	8%	677	53%	475	37%	0	0%	13	1%
Central	122	240	82	34%	53	22%	92	38%	1	0%	12	5%
Basin	123	314	30	10%	127	40%	147	47%	3	1%	7	2%
7	124	729	182	25%	212	29%	138	19%	190	26%	7	1%
Port	125	852	280	33%	319	37%	135	16%	103	12%	15	2%
Madison	126	637	219	34%	176	28%	130	20%	101	16%	11	2%
8	113	231	85	37%	50	22%	91	39%	2	1%	3	1%
West Point	127	447	149	33%	156	35%	137	31%	0	0%	5	1%
	128	568	201	35%	139	24%	222	39%	1	0%	5	1%

Table 22. Continued.

Stratum	Sample	Total Abundance	Annelida	Annelida % of total abundance	Arthropoda	Arthropoda % of total abundance	Mollusca	Mollusca % of total abundance	Echino-dermata	Echinodermata % of total abundance	Misc. Taxa	Misc. Taxa % of total abundance
	129	424	154	36%	118	28%	136	32%	1	0%	15	4%
9	130	863	541	63%	93	11%	218	25%	4	0%	7	1%
Eagle	131	762	339	44%	244	32%	172	23%	3	0%	4	1%
Harbor	132	1455	1143	79%	201	14%	105	7%	2	0%	4	0%
10	133	531	124	23%	178	34%	179	34%	32	6%	18	3%
Central	134	363	76	21%	184	51%	87	24%	5	1%	11	3%
Basin	135	304	180	59%	43	14%	70	23%	3	1%	8	3%
11	136	198	63	32%	71	36%	53	27%	0	0%	11	6%
Central	137	230	85	37%	67	29%	66	29%	0	0%	12	5%
Basin	138	168	50	30%	79	47%	28	17%	2	1%	9	5%
12	139	337	81	24%	94	28%	151	45%	2	1%	9	3%
East	140	144	63	44%	46	32%	29	20%	2	1%	4	3%
Passage	141	265	177	67%	38	14%	33	12%	3	1%	14	5%
13	142	325	109	34%	102	31%	4	1%	107	33%	3	1%
Liberty	143	309	171	55%	75	24%	32	10%	31	10%	0	0%
Bay	144	293	56	19%	105	36%	40	14%	90	31%	2	1%
14	145	354	179	51%	61	17%	107	30%	3	1%	4	1%
Keyport	146	650	63	10%	200	31%	34	5%	353	54%	0	0%
	147	543	354	65%	25	5%	149	27%	4	1%	11	2%
15	148	349	112	32%	31	9%	69	20%	135	39%	2	1%
North	149	810	204	25%	112	14%	466	58%	13	2%	15	2%
West	150	435	136	31%	17	4%	127	29%	148	34%	7	2%

Table 22. Continued.

Stratum	Sample	Total Abundance	Annelida	Annelida % of total abundance	Arthropoda	Arthropoda % of total abundance	Mollusca	Mollusca % of total abundance	Echino-dermata	Echinodermata % of total abundance	Misc. Taxa	Misc. Taxa % of total abundance
16	151	337	99	29%	14	4%	70	21%	144	43%	10	3%
South	152	859	165	19%	122	14%	475	55%	86	10%	11	1%
West	153	243	83	34%	8	3%	87	36%	58	24%	7	3%
17	154	659	199	30%	41	6%	395	60%	5	1%	19	3%
Rich	155	951	93	10%	138	15%	709	75%	0	0%	11	1%
Passage	156	573	234	41%	189	33%	105	18%	19	3%	26	5%
18	157	808	163	20%	159	20%	443	55%	37	5%	6	1%
Port	158	631	241	38%	84	13%	265	42%	26	4%	15	2%
Orchard	159	563	137	24%	122	22%	241	43%	46	8%	17	3%
19	160	149	132	89%	3	2%	9	6%	0	0%	5	3%
Sinclair	161	1283	1165	91%	52	4%	41	3%	24	2%	1	0%
Inlet	162	559	220	39%	166	30%	64	11%	105	19%	4	1%
20	163	565	326	58%	113	20%	33	6%	86	15%	7	1%
Sinclair	164	1336	1067	80%	132	10%	108	8%	21	2%	8	1%
Inlet	165	663	269	41%	277	42%	34	5%	73	11%	10	2%
21	166	651	196	30%	162	25%	270	41%	5	1%	18	3%
Dyes Inlet	167	826	412	50%	156	19%	221	27%	22	3%	15	2%
	168	1232	1103	90%	30	2%	93	8%	2	0%	4	0%
22	169	1574	1123	71%	248	16%	179	11%	17	1%	7	0%
Dyes Inlet	170	894	266	30%	364	41%	57	6%	200	22%	7	1%
	171	1113	260	23%	574	52%	48	4%	224	20%	7	1%

Table 22. Continued.

Stratum	Sample	Total Abundance	Annelida	Annelida % of total abundance	Arthropoda	Arthropoda % of total abundance	Mollusca	Mollusca % of total abundance	Echino-dermata	Echinodermata % of total abundance	Misc. Taxa	Misc. Taxa % of total abundance
23	172	188	69	37%	48	26%	60	32%	0	0%	11	6%
Outer	173	470	174	37%	56	12%	230	49%	5	1%	5	1%
Elliott Bay	174	494	308	62%	83	17%	64	13%	30	6%	9	2%
	175	631	352	56%	114	18%	114	18%	28	4%	23	4%
24	176	876	501	57%	97	11%	255	29%	12	1%	11	1%
Shoreline	177	1378	78	6%	475	34%	822	60%	1	0%	2	0%
Elliott Bay	178	343	179	52%	104	30%	56	16%	1	0%	3	1%
25	115	1161	1092	94%	9	1%	60	5%	0	0%	0	0%
Shoreline	179	478	254	53%	83	17%	137	29%	0	0%	4	1%
Elliott Bay	180	639	350	55%	66	10%	215	34%	3	0%	5	1%
	181	457	212	46%	88	19%	142	31%	2	0%	13	3%
26	182	571	309	54%	37	6%	188	33%	21	4%	16	3%
Shoreline	183	740	435	59%	133	18%	159	21%	3	0%	10	1%
Elliott Bay	184	731	488	67%	57	8%	177	24%	2	0%	7	1%
27	185	269	106	39%	57	21%	101	38%	1	0%	4	1%
Mid Elliott	186	655	169	26%	84	13%	392	60%	3	0%	7	1%
Bay	187	334	69	21%	30	9%	227	68%	1	0%	7	2%
	188	825	166	20%	72	9%	563	68%	8	1%	16	2%
28	189	928	361	39%	312	34%	219	24%	28	3%	8	1%
Mid Elliott	190	1717	114	7%	909	53%	688	40%	0	0%	6	0%
Bay	191	328	155	47%	36	11%	132	40%	1	0%	4	1%
	192	883	608	69%	112	13%	151	17%	7	1%	5	1%
29	193	848	219	26%	21	2%	603	71%	0	0%	5	1%

Table 22. Continued.

Stratum	Sample	Total Abundance	Annelida	Annelida % of total abundance	Arthropoda	Arthropoda % of total abundance	Mollusca	Mollusca % of total abundance	Echino-dermata	Echinodermata % of total abundance	Misc. Taxa	Misc. Taxa % of total abundance
Mid Elliott	194	456	184	40%	10	2%	261	57%	0	0%	1	0%
Bay	195	365	271	74%	46	13%	44	12%	1	0%	3	1%
	196	471	131	28%	18	4%	320	68%	2	0%	0	0%
30	114	1077	982	91%	21	2%	73	7%	0	0%	1	0%
West	197	806	394	49%	103	13%	304	38%	1	0%	4	0%
Harbor	198	1128	259	23%	347	31%	511	45%	0	0%	11	1%
Island	199	1391	473	34%	406	29%	495	36%	11	1%	6	0%
31	200	980	802	82%	27	3%	149	15%	0	0%	2	0%
East	201	1415	1281	91%	37	3%	95	7%	0	0%	2	0%
Harbor	202	1572	891	57%	23	1%	657	42%	0	0%	1	0%
32	203	3764	2970	79%	94	2%	688	18%	0	0%	12	0%
Duwamish	204	1155	1002	87%	31	3%	117	10%	1	0%	4	0%
	205	1561	1314	84%	17	1%	226	14%	1	0%	3	0%

Table 23. Total abundance, taxa richness, Pielou's evenness, and Swartz's Dominance Index for the 1998 central Puget Sound sampling stations.

Stratum	Sample	Total Abundance	Taxa Richness	Pielou's Evenness (J')	Swartz's Dominance Index
1	106	302	62	0.849	20
South Port Townsend	107	580	81	0.822	24
	108	707	47	0.596	6
2	109	702	131	0.835	34
Port Townsend	110	410	68	0.794	18
	111	807	111	0.768	23
4	112	2325	176	0.540	17
South Admiralty Inlet	116	554	53	0.705	8
	117	227	50	0.807	15
5	118	110	46	0.910	19
Possession Sound	119	197	35	0.727	8
	120	201	33	0.727	6
6	121	1272	60	0.577	5
Central Basin	122	240	46	0.841	14
	123	314	31	0.696	5
7	124	729	73	0.732	12
Port Madison	125	852	87	0.758	14
	126	637	93	0.777	18
8	113	231	37	0.782	9
West Point	127	447	51	0.789	11
	128	568	68	0.642	7
	129	424	62	0.766	13
9	130	863	95	0.732	17
Eagle Harbor	131	762	56	0.671	8
	132	1455	82	0.490	5
10	133	531	77	0.734	16
Central Basin	134	363	54	0.679	9
	135	304	73	0.855	22
11	136	198	38	0.809	11

Table 23. Continued.

Stratum	Sample	Total Abundance	Taxa Richness	Pielou's Evenness (J')	Swartz's Dominance Index
Central Basin	137	230	40	0.820	10
	138	168	40	0.821	13
12	139	337	55	0.719	10
East Passage	140	144	35	0.832	11
	141	265	79	0.909	33
13	142	325	26	0.702	6
Liberty Bay	143	309	28	0.740	7
	144	293	28	0.693	7
14	145	354	48	0.869	16
Keyport	146	650	28	0.560	3
	147	543	85	0.748	17
15	148	349	33	0.763	8
North West Bainbridge	149	810	73	0.665	13
	150	435	44	0.702	7
16	151	337	37	0.716	6
South West Bainbridge	152	859	87	0.690	15
	153	243	40	0.837	14
17	154	659	99	0.772	23
Rich Passage	155	951	68	0.606	6
	156	573	102	0.815	24
18	157	808	90	0.673	12
Port Orchard	158	631	113	0.763	27
	159	563	99	0.819	28
19	160	149	21	0.633	4
Sinclair Inlet	161	1283	32	0.387	2
	162	559	44	0.706	7
20	163	565	32	0.686	6
Sinclair Inlet	164	1336	53	0.498	5
	165	663	36	0.689	6
21	166	651	85	0.789	20
Port Washington	167	826	79	0.691	10

Table 23. Continued.

Stratum	Sample	Total Abundance	Taxa Richness	Pielou's Evenness (J')	Swartz's Dominance Index
Narrows					
	168	1232	48	0.261	1
22	169	1574	74	0.650	9
Dyes Inlet	170	894	33	0.583	4
	171	1113	39	0.552	4
23	172	188	43	0.809	13
Outer Elliott Bay	173	470	56	0.591	6
	174	494	127	0.834	38
	175	631	137	0.894	48
24	176	876	113	0.771	22
Shoreline Elliott Bay	177	1378	61	0.515	4
	178	343	80	0.783	21
25	115	1161	43	0.255	1
Shoreline Elliott Bay	179	478	69	0.731	12
	180	639	77	0.793	19
	181	457	85	0.833	27
26	182	571	88	0.792	23
Shoreline Elliott Bay	183	740	105	0.795	23
	184	731	89	0.791	21
27	185	269	32	0.739	9
Mid Elliott Bay	186	655	70	0.613	9
	187	334	46	0.473	5
	188	825	67	0.507	5
28	189	928	102	0.705	17
Mid Elliott Bay	190	1717	71	0.445	3
	191	328	57	0.694	12
	192	883	91	0.706	14
29	193	848	56	0.413	3
Mid Elliott Bay	194	456	46	0.539	4
	195	365	67	0.789	16
	196	471	42	0.451	3
30	114	1077	47	0.386	2

Table 23. Continued.

Stratum	Sample	Total Abundance	Taxa Richness	Pielou's Evenness (J')	Swartz's Dominance Index
West Harbor Island	197	806	71	0.679	12
	198	1128	90	0.633	9
	199	1391	84	0.653	10
31	200	980	56	0.598	5
East Harbor Island	201	1415	57	0.386	2
	202	1572	42	0.446	3
32	203	3764	94	0.426	3
Duwamish	204	1155	52	0.373	2
	205	1561	65	0.454	3

Table 24. Spearman-rank correlation coefficients (rho, corrected for ties) and significance levels (p) between benthic infaunal indices and measures of grain size (% fines) and % TOC for all 1998 central Puget Sound sites (n=100).

Benthic index	% Fines	(p)	% TOC	(p)
Total Abundance	-0.26	**	-0.132	ns
Taxa Richness	-0.66	****	-0.601	****
Pielou's Evenness (J')	-0.164	ns	-0.219	*
Swartz's Dominance Index	-0.422	****	-0.428	****
Annelid Abundance	-0.16	ns	-0.016	ns
Arthropod Abundance	-0.316	**	-0.306	**
Mollusca Abundance	-0.431	****	-0.374	***
Echinoderm Abundance	0.087	ns	0.149	ns
Miscellaneous Taxa Abundance	-0.358	***	-0.41	****

ns = p > 0.05
* = $p \leq 0.05$
** = $p \leq 0.01$
*** = $p \leq 0.001$
**** = $p \leq 0.0001$

Table 25. Spearman-rank correlations coefficients (rho, corrected for ties) and significance levels (p) for nine indices of benthic infaunal structure and results of four toxicity tests for all 1998 central Puget Sound sites (n=100).

Benthic index	Amphipod survival	(p)	Urchin fertilization	(p)	Microbial bioluminescence	(p)	Cytochrome P450 HRGS	(p)
Total Abundance	0.079	ns	-0.29	**	-0.137	ns	0.263	**
Taxa Richness	-0.06	ns	-0.08	ns	0.306	**	-0.122	ns
Pielou's Evenness (J')	-0.16	ns	0.177	ns	0.149	ns	-0.38	****
Swartz's Dominance Index	-0.176	ns	0.106	ns	0.257	**	-0.351	***
Annelid Abundance	-0.052	ns	-0.391	****	-0.113	ns	0.427	****
Arthropod Abundance	0.082	ns	0.186	ns	-0.014	ns	-0.241	*
Mollusca Abundance	0.076	ns	-0.008	ns	0.286	**	0.019	ns
Echinoderm Abundance	-0.077	ns	0.072	ns	-0.285	**	-0.161	ns
Miscellaneous Taxa Abundance	-0.152	ns	0.036	ns	0.172	ns	-0.319	**

ns = p > 0.05
* = p ≤ 0.05
** = p ≤ 0.01
*** = p ≤ 0.001
**** = p ≤ 0.0001

Table 26. Spearman-rank correlation coefficients (rho, corrected for ties) and significance levels (p) for nine indices of benthic infaunal structure and concentrations of trace metals, chlorinated organic hydrocarbons, and total PAHs, normalized to their respective ERM, SQS, and CSL values for all 1998 central Puget Sound sites (n=100).

Chemical	Total Abund-ance (p)	Taxa Richness (p)	Pielou's Evenness (J') (p)	Swartz's Domi-nance (p)	Annelida Abundance (p)	Arthropoda Abundance (p)	Mollusca Abundance (p)	Echino-dermata Abund-ance (p)	Misc. Taxa Abun-dance (p)
ERM values									
mean ERM quotients for 9 trace metals	-0.025 ns	-0.5 ****	-0.324 *	-0.455 ****	0.062 ns	-0.225 ns	-0.218 ns	-0.097 ns	-0.378 **
mean ERM quotients for 3 chlorinated organic hydrocarbons	0.258 ns	-0.031 ns	-0.327 *	-0.288 *	0.454 ****	-0.281 ns	0.122 ns	-0.315 *	-0.266 ns
mean ERM quotients for 13 polynuclear aromatic hydrocarbons	0.262 ns	-0.08 ns	-0.354 **	-0.315 *	0.44 ****	-0.249 ns	0.079 ns	-0.239 ns	-0.308 *
mean ERM quotients for 25 substances	0.218 ns	-0.15 ns	-0.355 **	-0.352 **	0.403 ***	-0.298 *	0.03 ns	-0.283 ns	-0.358 **
SQS values									
mean SQS quotients for 8 trace metals	0.005 ns	-0.466 ****	-0.331 **	-0.443 ****	0.135 ns	-0.28 ns	-0.197 ns	-0.006 ns	-0.369 **
mean SQS quotients for 6 low molecular weight polynuclear aromatic hydrocarbons	0.352 **	0.411 ***	-0.186 ns	0.028 ns	0.438 ****	-0.091 ns	0.418 ***	-0.419 ***	-0.025 ns
mean SQS quotients for 9 high molecular weight polynuclear aromatic hydrocarbons	0.41 ***	0.301 *	-0.278 ns	-0.08 ns	0.554 ****	-0.094 ns	0.302 *	-0.254 ns	-0.084 ns

Table 26. Continued.

Chemical	Total Abundance (p)	Taxa Richness (p)	Pielou's Evenness (J') (p)	Swartz's Dominance (p)	Annelida Abundance (p)	Arthropoda Abundance (p)	Mollusca Abundance (p)	Echinodermata Abundance (p)	Misc. Taxa Abundance (p)
mean SQS quotients for 15 polynuclear aromatic hydrocarbons	0.416 ***	0.33 **	-0.268 ns	-0.066 ns	0.545 ****	-0.086 ns	0.333 **	-0.29 *	-0.075 ns
CSL values									
mean CSL quotients for 8 trace metals	0.003 ns	-0.47 ****	-0.332 **	-0.445 ****	0.132 ns	-0.282 ns	-0.197 ns	-0.002 ns	-0.373 **
mean CSL quotients for 6 low molecular weight polynuclear aromatic hydrocarbons	0.312 *	0.388 ***	-0.161 ns	0.038 ns	0.42 ***	-0.105 ns	0.381 **	-0.418 ***	-0.037 ns
mean CSL quotients for 9 high molecular weight polynuclear aromatic hydrocarbons	0.413 ***	0.293 *	-0.283 ns	-0.089 ns	0.553 ****	-0.092 ns	0.3 *	-0.249 ns	-0.085 ns
mean CSL quotients for 15 polynuclear aromatic hydrocarbons	0.414 ***	0.325 *	-0.271 ns	-0.068 ns	0.543 ****	-0.084 ns	0.328 *	-0.281 ns	-0.075 ns

ns = $p > 0.05$
* = $p \leq 0.05$
** = $p \leq 0.01$
*** = $p \leq 0.001$
**** = $p \leq 0.0001$

Table 27. Spearman-rank correlation coefficients (rho, corrected for ties) and significance levels (p) for nine indices of benthic infaunal structure and concentrations of partial digestion metals in sediments for all 1998 central Puget Sound sites (n=100).

Chemical	Total Abund-ance	(p)	Taxa Richness	(p)	Pielou's Evenness (J')	(p)	Swartz's Domi-nance	(p)	Annelida Abundance	(p)	Arthro-poda Abund-ance	(p)	Mollusca Abundance	(p)	Echino-dermata Abund-ance	(p)	Misc. Taxa Abun-dance	(p)
Aluminum	-0.263	ns	-0.648	****	-0.156	ns	-0.432	**	-0.165	ns	-0.363	*	-0.387	*	-0.027	ns	-0.396	**
Antimony	0.299	ns	-0.096	ns	-0.131	ns	-0.075	ns	0.133	ns	0.389	ns	0.11	ns	0.068	ns	0.001	ns
Arsenic	-0.015	ns	-0.453	***	-0.307	ns	-0.438	***	0.146	ns	-0.319	ns	-0.246	ns	-0.156	ns	-0.375	*
Barium	-0.074	ns	-0.395	**	-0.232	ns	-0.382	*	0.057	ns	-0.372	*	-0.115	ns	-0.289	ns	-0.332	ns
Beryllium	-0.271	ns	-0.522	****	-0.125	ns	-0.365	*	-0.183	ns	-0.406	**	-0.249	ns	-0.175	ns	-0.249	ns
Cadmium	-0.016	ns	-0.621	****	-0.245	ns	-0.513	****	-0.012	ns	-0.124	ns	-0.383	*	0.183	ns	-0.418	**
Calcium	-0.097	ns	-0.443	***	-0.105	ns	-0.256	ns	-0.028	ns	-0.18	ns	-0.311	ns	0.189	ns	-0.18	ns
Chromium	-0.267	ns	-0.699	****	-0.174	ns	-0.43	**	-0.191	ns	-0.254	ns	-0.43	**	0.07	ns	-0.404	**
Cobalt	-0.414	**	-0.49	****	-0	ns	-0.231	ns	-0.305	ns	-0.337	ns	-0.319	ns	-0.227	ns	-0.21	ns
Copper	0.056	ns	-0.454	***	-0.36	*	-0.475	***	0.201	ns	-0.276	ns	-0.222	ns	-0.049	ns	-0.376	*
Iron	-0.303	ns	-0.608	****	-0.095	ns	-0.371	*	-0.194	ns	-0.38	*	-0.368	*	-0.169	ns	-0.352	ns
Lead	0.095	ns	-0.365	*	-0.362	*	-0.428	**	0.233	ns	-0.299	ns	-0.134	ns	-0.069	ns	-0.335	ns
Magnesium	-0.44	***	-0.697	****	0.009	ns	-0.305	ns	-0.357	*	-0.271	ns	-0.512	****	0.078	ns	-0.328	ns
Manganese	-0.499	****	-0.416	**	0.112	ns	-0.11	ns	-0.393	**	-0.336	ns	-0.345	ns	-0.207	ns	-0.086	ns
Mercury	0.035	ns	-0.403	**	-0.323	ns	-0.403	**	0.148	ns	-0.265	ns	-0.137	ns	0.024	ns	-0.333	ns
Nickel	-0.432	**	-0.655	****	0.047	ns	-0.249	ns	-0.378	*	-0.179	ns	-0.489	****	0.141	ns	-0.314	ns
Potassium	-0.351	ns	-0.671	****	-0.092	ns	-0.378	*	-0.261	ns	-0.334	ns	-0.473	***	0.012	ns	-0.331	ns
Selenium	-0.183	ns	-0.721	****	0.055	ns	-0.126	ns	-0.268	ns	0.213	ns	-0.569	**	0.478	ns	-0.108	ns
Silver	-0.102	ns	-0.62	****	-0.311	ns	-0.527	****	-0.049	ns	-0.337	ns	-0.269	ns	-0.116	ns	-0.362	ns
Sodium	-0.304	ns	-0.683	****	-0.123	ns	-0.397	**	-0.206	ns	-0.301	ns	-0.474	***	0.111	ns	-0.336	ns
Thallium	0.096	ns	-0.003	ns	0.024	ns	0.013	ns	0.145	ns	-0.065	ns	-0.036	ns	0.195	ns	-0.097	ns
Titanium	-0.105	ns	-0.598	****	-0.245	ns	-0.499	****	-0.074	ns	-0.256	ns	-0.28	ns	0.025	ns	-0.41	**
Vanadium	-0.183	ns	-0.56	****	-0.199	ns	-0.443	***	-0.1	ns	-0.4	**	-0.261	ns	-0.17	ns	-0.371	*
Zinc	-0.019	ns	-0.544	****	-0.319	ns	-0.493	****	0.101	ns	-0.306	ns	-0.293	ns	-0.071	ns	-0.387	*

ns = $p > 0.05$
* = $p \leq 0.05$
** = $p \leq 0.01$
*** = $p \leq 0.001$
**** = $p \leq 0.0001$

Table 28. Spearman-rank correlation coefficients (rho, corrected for ties) and significance levels (p) for nine indices of benthic infaunal structure and concentrations of total digestion metals in sediments for all 1998 central Puget Sound sites (n=100).

Chemical	Total Abund-ance	(p)	Taxa Rich-ness	(p)	Pielou's Evenness (J')	(p)	Swartz's Domi-nance	(p)	Annelida Abund-ance	(p)	Arthro-poda Abund-ance	(p)	Mollusca Abundance	(p)	Echino-dermata Abund-ance	(p)	Misc. Taxa Abun-dance	(p)
Aluminum	-0.04	ns	-0.05	ns	-0.059	ns	-0.12	ns	0.032	ns	-0.229	ns	0.078	ns	-0.273	ns	-0.05	ns
Antimony	0.077	ns	-0.264	ns	-0.322	ns	-0.347	ns	0.114	ns	-0.148	ns	-0.006	ns	-0.168	ns	-0.2	ns
Arsenic	-0.009	ns	-0.383	*	-0.291	ns	-0.408	**	0.132	ns	-0.343	ns	-0.167	ns	-0.203	ns	-0.31	ns
Barium	-0.032	ns	0.246	ns	0.114	ns	0.148	ns	-0.052	ns	-0.022	ns	0.254	ns	-0.269	ns	0.149	ns
Beryllium	-0.02	ns	-0.11	ns	-0.125	ns	-0.18	ns	-0.006	ns	-0.221	ns	0.155	ns	-0.547	****	-0.19	ns
Cadmium	0.033	ns	-0.403	ns	-0.279	ns	-0.431	*	-0.019	ns	-0.339	ns	-0.094	ns	-0.39	ns	-0.404	ns
Calcium	0.211	ns	0.198	ns	-0.105	ns	-0.024	ns	0.283	ns	-0.116	ns	0.181	ns	-0.107	ns	-0.092	ns
Chromium	-0.288	ns	-0.565	****	-0.029	ns	-0.245	ns	-0.27	ns	-0.024	ns	-0.39	*	0.103	ns	-0.267	ns
Cobalt	-0.211	ns	-0.266	ns	-0.053	ns	-0.198	ns	-0.088	ns	-0.205	ns	-0.16	ns	-0.32	ns	-0.134	ns
Copper	0.056	ns	-0.409	**	-0.319	ns	-0.418	**	0.192	ns	-0.222	ns	-0.197	ns	-0.04	ns	-0.287	ns
Iron	-0.069	ns	-0.361	*	-0.206	ns	-0.35	ns	0.01	ns	-0.321	ns	-0.12	ns	-0.398	**	-0.261	ns
Lead	0.077	ns	-0.363	*	-0.338	ns	-0.407	**	0.221	ns	-0.269	ns	-0.179	ns	-0.035	ns	-0.306	ns
Magnesium	-0.247	ns	-0.429	**	-0.094	ns	-0.285	ns	-0.16	ns	-0.325	ns	-0.212	ns	-0.202	ns	-0.227	ns
Manganese	-0.194	ns	-0.006	ns	0.074	ns	0.017	ns	-0.166	ns	-0.193	ns	0.033	ns	-0.488	****	-0.004	ns
Nickel	-0.343	ns	-0.655	****	-0.086	ns	-0.341	ns	-0.309	ns	-0.15	ns	-0.432	**	0.073	ns	-0.314	ns
Potassium	-0.138	ns	-0.287	ns	-0.102	ns	-0.253	ns	-0.112	ns	-0.239	ns	-0.086	ns	-0.332	ns	-0.092	ns
Selenium	-0.247	ns	-0.638	****	-0.145	ns	-0.365	ns	-0.238	ns	-0.077	ns	-0.397	ns	0.079	ns	-0.146	ns
Sodium	-0.197	ns	-0.53	****	-0.149	ns	-0.341	ns	-0.202	ns	-0.113	ns	-0.315	ns	0.103	ns	-0.193	ns
Thallium	0.072	ns	-0.111	ns	-0.085	ns	-0.113	ns	0.046	ns	0.155	ns	0.012	ns	-0.094	ns	-0.195	ns
Titanium	0.072	ns	-0.321	ns	-0.296	ns	-0.407	**	0.065	ns	-0.223	ns	-0.021	ns	-0.355	ns	-0.269	ns
Vanadium	-0.1	ns	-0.438	***	-0.208	ns	-0.392	*	-0.096	ns	-0.281	ns	-0.142	ns	-0.329	ns	-0.254	ns
Zinc	0.046	ns	-0.45	***	-0.337	ns	-0.461	***	0.145	ns	-0.241	ns	-0.211	ns	-0.101	ns	-0.311	ns
Silicon	0.247	ns	0.678	****	0.189	ns	0.441	***	0.176	ns	0.273	ns	0.401	**	-0.069	ns	0.328	ns
Tin	0.151	ns	-0.232	ns	-0.346	ns	-0.359	*	0.301	ns	-0.276	ns	-0.034	ns	-0.169	ns	-0.351	ns

ns = $p > 0.05$
* = $p \leq 0.05$
** = $p \leq 0.01$
*** = $p \leq 0.001$
**** = $p \leq 0.0001$

Table 29. Spearman-rank correlation coefficients (rho, corrected for ties) and significance levels (p) for nine indices of benthic infaunal structure and concentrations of Low Molecular Weight Polynuclear Aromatic Hydrocarbons (LPAH) in sediments for all 1998 central Puget Sound sites (n=100).

Chemical	Total Abund-ance	(p)	Taxa Richness	(p)	Pielou's Evenness (J')	(p)	Swartz's Domi-nance	(p)	Annelida Abund-ance	(p)	Arthro-poda Abund-ance	(p)	Mollusca Abundance	(p)	Echino-dermata Abund-ance	(p)	Misc. Taxa Abun-dance	(p)
1,6,7-Trimethylnaphthalene	0.057	ns	-0.211	ns	-0.196	ns	-0.258	ns	0.158	ns	-0.32	ns	0.008	ns	-0.239	ns	-0.229	ns
1-Methylnaphthalene	0.133	ns	-0.113	ns	-0.215	ns	-0.224	ns	0.194	ns	-0.293	ns	0.142	ns	-0.375	*	-0.254	ns
1-Methylphenanthrene	0.218	ns	-0.196	ns	-0.377	*	-0.381	*	0.287	ns	-0.211	ns	0.046	ns	-0.274	ns	-0.31	ns
2,6-Dimethylnaphthalene	0.087	ns	-0.474	***	-0.296	ns	-0.452	***	0.109	ns	-0.202	ns	-0.238	ns	0.028	ns	-0.353	ns
2-Methylnaphthalene	0.176	ns	-0.076	ns	-0.259	ns	-0.243	ns	0.239	ns	-0.299	ns	0.197	ns	-0.404	**	-0.274	ns
2-Methylphenanthrene	0.15	ns	-0.172	ns	-0.278	ns	-0.298	ns	0.253	ns	-0.238	ns	0.06	ns	-0.309	ns	-0.289	ns
Acenaphthene	0.337	ns	-0.026	ns	-0.389	*	-0.313	ns	0.436	**	-0.225	ns	0.197	ns	-0.35	ns	-0.302	ns
Acenaphthylene	0.247	ns	-0.094	ns	-0.341	ns	-0.307	ns	0.39	*	-0.207	ns	0.084	ns	-0.249	ns	-0.285	ns
Anthracene	0.307	ns	-0.039	ns	-0.387	*	-0.321	ns	0.457	***	-0.23	ns	0.124	ns	-0.235	ns	-0.313	ns
Biphenyl	0.176	ns	0.018	ns	-0.2	ns	-0.148	ns	0.291	ns	-0.261	ns	0.267	ns	-0.347	ns	-0.219	ns
Dibenzothiophene	0.312	ns	-0.066	ns	-0.376	ns	-0.353	ns	0.423	**	-0.199	ns	0.21	ns	-0.502	***	-0.411	*
Fluorene	0.237	ns	-0.093	ns	-0.352	ns	-0.329	ns	0.36	*	-0.254	ns	0.123	ns	-0.361	*	-0.331	ns
Naphthalene	0.191	ns	-0.01	ns	-0.259	ns	-0.205	ns	0.341	ns	-0.288	ns	0.185	ns	-0.403	*	-0.254	ns
Phenanthrene	0.242	ns	-0.108	ns	-0.342	ns	-0.323	ns	0.369	*	-0.253	ns	0.106	ns	-0.321	ns	-0.323	ns
Retene	0.152	ns	-0.181	ns	-0.291	ns	-0.298	ns	0.256	ns	-0.189	ns	-0.04	ns	-0.041	ns	-0.164	ns
Sum of 6 LPAH^	0.372	*	0.424	**	-0.192	ns	0.03	ns	0.456	***	-0.076	ns	0.426	**	-0.398	**	-0.018	ns
Sum of 7 LPAH^^	0.236	ns	-0.054	ns	-0.323	ns	-0.279	ns	0.408	**	-0.257	ns	0.1	ns	-0.282	ns	-0.299	ns
Total LPAH	0.229	ns	-0.088	ns	-0.328	ns	-0.293	ns	0.404	**	-0.258	ns	0.066	ns	-0.234	ns	-0.311	ns

^6 LPAH = defined by WA Ch. 173-204 RCW; Acenaphthene, Acenaphthylene, Anthracene, Fluorene, Naphthalene, Phenanthrene, carbon normalized.
^^7LPAH = defined by Long et. Al., 1995; Acenaphthene, Acenaphthylene, Anthracene, Fluorene, 2-Methylnaphthalene, Naphthalene, Phenanthrene
ns = p > 0.05
* = p $\leq$ 0.05
** = p $\leq$ 0.01
*** = p $\leq$ 0.001
**** = p $\leq$ 0.0001

Table 30. Spearman-rank correlation coefficients (rho, corrected for ties) and significance levels (p) for nine indices of benthic infaunal structure and concentrations of High Molecular Weight Polynuclear Aromatic Hydrocarbons (HPAH) in sediments for all 1998 central Puget Sound sites (n=100).

Chemical	Total Abundance	(p)	Taxa Richness	(p)	Pielou's Evenness (J')	(p)	Swartz's Dominance	(p)	Annelida Abundance	(p)	Arthropoda Abundance	(p)	Mollusca Abundance	(p)	Echinodermata Abundance	(p)	Misc. Taxa Abundance	(p)
Benzo(a)anthracene	0.291	ns	-0.096	ns	-0.388	*	-0.35	ns	0.451	***	-0.24	ns	0.076	ns	-0.21	ns	-0.321	ns
Benzo(a)pyrene	0.291	ns	-0.107	ns	-0.383	*	-0.344	ns	0.456	***	-0.223	ns	0.058	ns	-0.17	ns	-0.294	ns
Benzo(b)fluoranthene	0.266	ns	-0.118	ns	-0.37	*	-0.341	ns	0.451	***	-0.251	ns	0.038	ns	-0.186	ns	-0.322	ns
Benzo(e)pyrene	0.289	ns	-0.143	ns	-0.415	**	-0.394	**	0.453	***	-0.235	ns	0.034	ns	-0.208	ns	-0.35	ns
Benzo(g,h,i)perylene	0.245	ns	-0.163	ns	-0.368	*	-0.363	*	0.423	**	-0.265	ns	0.012	ns	-0.176	ns	-0.301	ns
Benzo(k)fluoranthene	0.262	ns	-0.134	ns	-0.372	*	-0.348	ns	0.441	***	-0.264	ns	0.028	ns	-0.173	ns	-0.352	ns
Chrysene	0.308	ns	-0.096	ns	-0.406	**	-0.359	*	0.477	****	-0.237	ns	0.074	ns	-0.202	ns	-0.325	ns
Dibenzo(a,h)anthracene	0.275	ns	-0.105	ns	-0.373	*	-0.343	ns	0.419	**	-0.253	ns	0.115	ns	-0.206	ns	-0.299	ns
Fluoranthene	0.269	ns	-0.084	ns	-0.356	*	-0.319	ns	0.458	***	-0.255	ns	0.063	ns	-0.2	ns	-0.321	ns
Indeno(1,2,3-c,d)pyrene	0.256	ns	-0.151	ns	-0.372	*	-0.361	*	0.436	***	-0.259	ns	0.025	ns	-0.178	ns	-0.307	ns
Perylene	0.136	ns	-0.225	ns	-0.307	ns	-0.354	ns	0.31	ns	-0.35	ns	-0.041	ns	-0.303	ns	-0.346	ns
Pyrene	0.241	ns	-0.077	ns	-0.328	ns	-0.291	ns	0.416	**	-0.199	ns	0.087	ns	-0.161	ns	-0.273	ns
sum of 6 HPAH^	0.281	ns	-0.092	ns	-0.373	*	-0.335	ns	0.453	***	-0.238	ns	0.073	ns	-0.201	ns	-0.312	ns
sum of 9 HPAH^^	0.407	**	0.315	ns	-0.27	ns	-0.07	ns	0.552	****	-0.089	ns	0.306	ns	-0.251	ns	-0.078	ns
Total HPAH	0.275	ns	-0.107	ns	-0.372	*	-0.34	ns	0.453	***	-0.247	ns	0.053	ns	-0.201	ns	-0.317	ns
sum of 13 PAH^^^	0.275	ns	-0.073	ns	-0.362	*	-0.319	ns	0.447	***	-0.238	ns	0.085	ns	-0.23	ns	-0.303	ns
Sum of 15 PAH^^^^	0.421	**	0.338	ns	-0.272	ns	-0.066	ns	0.544	****	-0.076	ns	0.341	ns	-0.281	ns	-0.062	ns
Total all PAH	0.265	ns	-0.099	ns	-0.365	*	-0.331	ns	0.44	***	-0.251	ns	0.066	ns	-0.219	ns	-0.312	ns

^6HPAH = defined by Long et. Al., 1995; Benzo(a)anthracene, Benzo(a)pyrene, Chrysene, Dibenzo(a,h)anthracene, Fluoranthene, Pyrene
^^9HPAH = defined by WA Ch. 173-204 RCW; Benzo(a)anthracene, Benzo(a)pyrene, Benzo(1,2,3,-c,d)pyrene, Benzo(g,h,i)perylene, Chrysene, Dibenzo(a,h)anthracene, Fluoranthene, Pyrene, Total Benzofluranthenes, carbon normalized
^^^13PAH = 7LPAH and 6HPAH
^^^^15PAH= 6LPAH and A11HPAH
ns = $p > 0.05$
* = $p \leq 0.05$
** = $p \leq 0.01$
*** = $p \leq 0.001$
**** = $p \leq 0.0001$

Table 31. Spearman-rank correlation coefficients (rho, corrected for ties) and significance levels (p) for nine indices of benthic infaunal structure and concentrations of DDT and PCB compounds in sediments for all 1998 central Puget Sound sites (n=100).

Chemical	Total Abund-ance	(p)	Taxa Richness	(p)	Pielou's Evenness (J')	(p)	Swartz's Domi-nance	(p)	Annelida Abund-ance	(p)	Arthropoda Abundance	(p)	Mollusca Abundance	(p)	Echinodermata Abundance	(p)	Misc. Taxa Abundance	(p)
4,4'-DDD	0.415	ns	0.066	ns	-0.056	ns	-0.059	ns	0.373	ns	-0.267	ns	0.058	ns	-0.056	ns	0.128	ns
4,4'-DDE	0.578	*	-0.083	ns	-0.604	**	-0.529	ns	0.465	ns	-0.387	ns	0.355	ns	-0.289	ns	-0.315	ns
Total DDT	0.573	*	-0.008	ns	-0.524	ns	-0.406	ns	0.467	ns	-0.32	ns	0.32	ns	-0.162	ns	-0.18	ns
PCB Aroclor 1242	0.786	ns	0.536	ns	-0.75	ns	-0.764	ns	0.857	ns	-0.393	ns	0.393	ns	0.06	ns	0.055	ns
PCB Aroclor 1254	0.454	ns	-0.009	ns	-0.543	**	-0.407	ns	0.399	ns	-0.275	ns	0.48	ns	-0.359	ns	-0.288	ns
PCB Aroclor 1260	0.408	ns	0.006	ns	-0.509	**	-0.392	ns	0.397	ns	-0.263	ns	0.3	ns	-0.254	ns	-0.299	ns
Total PCB Aroclor	0.407	ns	0.399	ns	-0.298	ns	-0.065	ns	0.439	ns	-0.162	ns	0.451	*	-0.383	ns	-0.154	ns
PCB Congener 8	0.543	ns	0.086	ns	-0.143	ns	0	ns	0.771	ns	-0.657	ns	-0.2	ns	0.145	ns	0	ns
PCB Congener 18	0.38	ns	-0.323	ns	-0.429	ns	-0.49	ns	0.381	ns	-0.356	ns	0.012	ns	-0.469	ns	-0.45	ns
PCB Congener 28	0.408	ns	0.107	ns	-0.431	ns	-0.343	ns	0.411	ns	-0.398	ns	0.448	ns	-0.41	ns	-0.315	ns
PCB Congener 44	0.345	ns	0.047	ns	-0.348	ns	-0.311	ns	0.35	ns	-0.32	ns	0.262	ns	-0.481	ns	-0.206	ns
PCB Congener 52	0.381	ns	0.13	ns	-0.403	ns	-0.278	ns	0.391	ns	-0.305	ns	0.451	ns	-0.38	ns	-0.231	ns
PCB Congener 66	0.359	ns	-0.03	ns	-0.517	**	-0.435	ns	0.348	ns	-0.36	ns	0.377	ns	-0.397	ns	-0.276	ns
PCB Congener 101	0.364	ns	-0.122	ns	-0.541	***	-0.475	**	0.371	ns	-0.315	ns	0.187	ns	-0.389	ns	-0.386	ns
PCB Congener 105	0.387	ns	0.161	ns	-0.401	ns	-0.281	ns	0.362	ns	-0.276	ns	0.386	ns	-0.498	*	-0.245	ns
PCB Congener 118	0.247	ns	-0.185	ns	-0.439	*	-0.405	ns	0.306	ns	-0.357	ns	0.107	ns	-0.404	ns	-0.343	ns
PCB Congener 128	0.365	ns	-0.055	ns	-0.439	ns	-0.39	ns	0.347	ns	-0.262	ns	0.237	ns	-0.237	ns	-0.226	ns
PCB Congener 138	0.308	ns	-0.036	ns	-0.427	ns	-0.334	ns	0.354	ns	-0.336	ns	0.253	ns	-0.381	ns	-0.315	ns
PCB Congener 153	0.239	ns	-0.215	ns	-0.465	**	-0.448	*	0.351	ns	-0.376	ns	0.049	ns	-0.38	ns	-0.368	ns
PCB Congener 170	0.342	ns	-0.156	ns	-0.544	**	-0.483	*	0.332	ns	-0.351	ns	0.29	ns	-0.408	ns	-0.306	ns
PCB Congener 180	0.328	ns	-0.074	ns	-0.455	*	-0.382	ns	0.382	ns	-0.29	ns	0.255	ns	-0.37	ns	-0.184	ns
PCB Congener 187	0.42	ns	-0.184	ns	-0.545	*	-0.534	*	0.406	ns	-0.367	ns	0.142	ns	-0.326	ns	-0.176	ns
PCB Congener 195	0.383	ns	-0.371	ns	-0.453	ns	-0.54	ns	0.309	ns	-0.334	ns	0.017	ns	-0.354	ns	-0.258	ns
PCB Congener 206	0.27	ns	-0.406	ns	-0.52	*	-0.549	**	0.235	ns	-0.323	ns	0.039	ns	-0.184	ns	-0.36	ns
Total PCB Congeners	0.213	ns	-0.175	ns	-0.415	*	-0.389	ns	0.393	ns	-0.385	ns	0.063	ns	-0.356	ns	-0.364	ns

ns = $p > 0.05$
* = $p \leq 0.05$
** = $p \leq 0.01$
*** = $p \leq 0.001$
**** = $p \leq 0.0001$

Table 32. Spearman-rank correlation coefficients (rho, corrected for ties) and significance levels (p) for nine indices of benthic infaunal structure and concentrations of organotins and organic compounds in sediments for all 1998 central Puget Sound sites (n=100).

Chemical	Total Abund-ance	(p)	Taxa Richness	(p)	Pielou's Evenness (J')	(p)	Swartz's Domi-nance	(p)	An-nelida Abund-ance	(p)	Arthrop-oda Abund-ance	(p)	Mollusca Abund-ance	(p)	Echino-dermata Abund-ance	(p)	Misc. Taxa Abun-dance	(p)
Organotins																		
Dibutyltin Dichloride	0.48	*	0.066	ns	-0.518	**	-0.353	ns	0.502	**	-0.181	ns	0.234	ns	-0.135	ns	-0.207	ns
Tributyltin Chloride	0.241	ns	-0.104	ns	-0.427	*	-0.372	ns	0.402	*	-0.341	ns	0.131	ns	-0.312	ns	-0.283	ns
Phenols																		
2,4-Dimethylphenol	-0.017	ns	0.175	ns	0.009	ns	0.056	ns	0.086	ns	-0.079	ns	0.09	ns	-0.215	ns	0.213	ns
2-Methylphenol	0.098	ns	-0.409	ns	-0.327	ns	-0.47	*	-0.038	ns	-0.069	ns	-0.184	ns	0.223	ns	-0.258	ns
4-Methylphenol	-0.003	ns	-0.389	*	-0.217	ns	-0.378	*	0.045	ns	-0.348	ns	-0.133	ns	-0.339	ns	-0.503	****
Pentachlorophenol	-0.087	ns	-0.012	ns	0.211	ns	0.058	ns	0.191	ns	-0.168	ns	-0.22	ns	0.429	ns	-0.107	ns
Phenol	-0.357	ns	-0.728	****	-0.039	ns	-0.47	ns	-0.245	ns	-0.14	ns	-0.652	**	0.174	ns	-0.422	ns
Miscellaneous																		
1,2-Dichlorobenzene	0.6	ns	-0.4	ns	-0.8	ns	-0.8	ns	0.8	ns	-0.8	ns	-0.4	ns	-0.894	ns	-0.316	ns
1,4-Dichlorobenzene	0.248	ns	0.016	ns	-0.178	ns	-0.192	ns	0.378	ns	-0.31	ns	-0.012	ns	-0.283	ns	-0.029	ns
Benzoic Acid	0.025	ns	-0.452	**	-0.225	ns	-0.414	**	-0.025	ns	-0.137	ns	-0.231	ns	0.296	ns	-0.137	ns
Benzyl Alcohol	-0.034	ns	-0.528	ns	-0.188	ns	-0.412	ns	-0.158	ns	0.044	ns	-0.112	ns	0.425	ns	-0.203	ns
Bis(2-Ethylhexyl) Phthalate	0.471	ns	-0.702	ns	-0.662	ns	-0.689	ns	0.365	ns	-0.416	ns	-0.152	ns	-0.511	ns	-0.552	ns
Butylbenzylphthalate	0.594	ns	-0.156	ns	-0.442	ns	-0.506	ns	0.597	ns	-0.084	ns	0.106	ns	-0.194	ns	-0.442	ns
Dibenzofuran	0.248	ns	-0.108	ns	-0.352	ns	-0.343	ns	0.319	ns	-0.266	ns	0.178	ns	-0.367	*	-0.369	*
Diethylphthalate	-0.197	ns	-0.086	ns	-0.018	ns	-0.032	ns	-0.12	ns	-0.146	ns	0.231	ns	0.217	ns	-0.033	ns
Dimethylphthalate	0.294	ns	0.413	ns	0.175	ns	0.109	ns	0.28	ns	-0.182	ns	0.483	ns	0.026	ns	0.385	ns
Di-N-Butylphthalate	0.226	ns	0.013	ns	-0.178	ns	-0.086	ns	-0.021	ns	0.183	ns	0.081	ns	0.298	ns	0.246	ns
Hexachlorobenzene	0.437	ns	-0.042	ns	-0.456	ns	-0.507	ns	0.442	ns	-0.149	ns	0.044	ns	-0.185	ns	-0.179	ns

ns = p > 0.05
* = $p \leq 0.05$
** = $p \leq 0.01$
*** = $p \leq 0.001$
**** = $p \leq 0.0001$

Table 33. Triad results for 1998 central Puget Sound stations with significant results for both chemistry and toxicity parameters.

Stratum, Sample, Location	Number of ERLs exceeded	Number of ERMs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Number of SQSs exceeded	Compounds exceeding SQSs	Number of CSLs exceeded	Compounds excceding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
1, 106, South Port Town-send			0.07		1	4-Methylphenol	1	4-Methylphenol	93.88	*	118.63		1.37		7.1		302	62	0.85	20	149	47	95	8	3	Acila castrensis	37
																										Paraprionospio pinnata	36
																										Eudorella (Tridentata) pacifica	20
																										Parvilucina tenuisculpta	17
																										Scoletoma luti	13
																										Lumbrineris californiensis	12
																										Rochefortia tumida	11
																										Nutricola lordi	11
																										Prionospio steenstrupi	10
																										Heterophoxus affinis	7
6, 123, Central Basin	1		0.10		1	4-Methylphenol	1	4-Methylphenol	85.71	*	117.92		5.37		6.1		314	31	0.70	5	30	127	147	3	7	Macoma carlottensis	80
																										Euphilomedes producta	55
																										Eudorella (Tridentata) pacifica	54
																										Macoma sp.	42
																										Lirobittium sp.	8
																										Prionospio (Minuspio) light	7
																										Axinopsida serricata	7
																										Nephtys cornuta	6
																										Paranemertes californica	5
																										Dyopedos arcticus	5
8, 113, West Point			0.09		1	4-Methylphenol	1	4-Methylphenol	95.92		118.16		2.90		11.7	++	231	37	0.77	13	85	50	91	2	3	Axinopsida serricata	56
																										Euphilomedes producta	28
																										Levinsenia gracilis	20
																										Prionospio (Minuspio) light	18
																										Parvilucina tenuisculpta	14
																										Macoma carlottensis	13
																										Ampharete cf. crassiseta	9
																										Pinnixa schmitti	9
																										Nephtys ferruginea	7
																										Cossura pygodactylata	6

Table 33. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Number of ERMs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Number of SQSs exceeded	Compounds exceeding SQSs	Number of CSLs exceeded	Compounds excceding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
12, 140, East Pas-sage	4		0.13		1	4-Methylphenol	1	4-Methylphenol	97.78		105.44		3.63		23.8	++	144	35	0.83	11	63	46	29	2	4	Axinopsida serricata	22
																										Levinsenia gracilis	20
																										Eudorella (Tridentata) pacifica	17
																										Cossura bansei	12
																										Spiophanes berkeleyorum	9
																										Euphilomedes producta	8
																										Eudorellopsis integra	7
																										Prionospio (Minuspio) light	5
																										Macoma carlottensis	4
																										Paraprionospio pinnata	3
15, 148, NW Bain-bridge Island	3		0.12		1	4-Methylphenol	1	4-Methylphenol	98.86		105.66		0.94		26.4	++	349	33	0.76	8	112	31	69	135	2	Amphiodia sp.	82
																										Acteocina culcitella	48
																										Amphiodia urtica/periercta complex	44
																										Eudorella (Tridentata) pacifica	24
																										Spiophanes berkeleyorum	21
																										Lumbrineris cruzensis	16
																										Terebellides californica	14
																										Pholoe sp. N1	13
																										Heteromastus filobranchus	12
																										Acila castrensis	9
16, 151, SW Bain-bridge Island	5		0.18		1	Benzyl Alcohol	1	Benzyl Alcohol	98.95		106.30		0.82		31.6	++	337	37	0.72	6	99	14	70	144	10	Amphiodia sp.	69
																										Amphiodia urtica/periercta complex	64
																										Pholoe sp. N1	36
																										Acila castrensis	35
																										Terebellides californica	34
																										Acteocina culcitella	17
																										Amphiuridae	11
																										Pinnixa occidentalis	9
																										Odostomia sp.	8
																										Cossura pygodactylata	6

Table 33. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Number of ERMs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Number of SQSs exceeded	Compounds exceeding SQSs	Number of CSLs exceeded	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
19, 160, Sinclair Inlet	9	1	0.35	Mercury	1	Mercury	1	Mercury	99.00		2.00	**	0.81		29.4	++	149	21	0.63	4	132	3	9	0	5	Aphelochaeta sp. N1	73
																										Paraprionospio pinnata	23
																										Terebellides californica	11
																										Nephtys cornuta	9
																										Micrura sp.	5
																										Chaetozone nr. setosa	4
																										Podarke pugettensis	3
																										Odostomia sp.	3
																										Crangon alaskensis	2
																										Spiophanes berkeleyorum	2
19, 161, Sinclair Inlet	7		0.27		1	Mercury	1	Mercury	104.40		103.00		0.82		44.5	+++	1283	32	0.39	2	1165	52	41	24	1	Aphelochaeta sp. N1	856
																										Nephtys cornuta	209
																										Eudorella (Tridentata) pacifica	34
																										Lumbrineris cruzensis	33
																										Terebellides californica	23
																										Amphiodia urtica/periercta complex	18
																										Axinopsida serricata	15
																										Pinnixa schmitti	15
																										Odostomia sp.	12
																										Paraprionospio pinnata	8
19, 162, Sinclair Inlet	8	1	0.30	Mercury	1	Mercury	1	Mercury	86.81		113.00		1.63		35.5	++	559	44	0.71	7	220	166	64	105	4	Eudorella (Tridentata) pacifica	102
																										Amphiodia urtica/periercta complex	96
																										Aphelochaeta monilaris	90
																										Pinnixa schmitti	44
																										Acila castrensis	42
																										Phyllochaetopterus prolifica	38
																										Lumbrineris cruzensis	21
																										Pholoe sp. N1	14
																										Terebellides californica	13
																										Amphiodia sp.	9

Table 33. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Number of ERMs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Number of SQSs exceeded	Compounds exceeding SQSs	Number of CSLs exceeded	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
20, 163, Sinclair Inlet	8	1	0.44	Mercury	1	Mercury	1	Mercury	93.41		113.00		1.02		27.7	++	565	32	0.69	6	326	113	33	86	7	Aphelochaeta sp. N1	186
																										Amphiodia urtica/periercta complex	83
																										Eudorella (Tridentata) pacifica	74
																										Pinnixa schmitti	35
																										Lumbrineris cruzensis	29
																										Terebellides californica	26
																										Pholoe sp. N1	25
																										Aphelochaeta monilaris	17
																										Cossura pygodactylata	11
																										Odostomia sp.	9
20, 164, Sinclair Inlet	9	1	0.42	Mercury	1	Mercury	1	Mercury	101.10		112.00		1.50		64.9	+++	1336	53	0.50	5	1067	132	108	21	8	Aphelochaeta sp. N1	782
																										Eudorella (Tridentata) pacifica	82
																										Scoletoma luti	80
																										Prionospio (Minuspio) light	42
																										Pinnixa schmitti	41
																										Odostomia sp.	32
																										Nutricola lordi	26
																										Aphelochaeta monilaris	25
																										Spiophanes berkeleyorum	23
																										Amphiodia urtica/periercta complex	20
20, 165, Sinclair Inlet	11	1	0.55	Mercury	1	Mercury	1	Mercury	100.00		81.00	**	6.83		39.4	+++	663	36	0.69	6	269	277	34	73	10	Eudorella (Tridentata) pacifica	199
																										Amphiodia urtica/periercta complex	73
																										Pinnixa schmitti	73
																										Lumbrineris cruzensis	70
																										Prionospio (Minuspio) light	57
																										Aphelochaeta sp. N1	36
																										Acila castrensis	21
																										Pholoe sp. N1	19
																										Aphelochaeta monilaris	14
																										Spiophanes berkeleyorum	14

Table 33. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Number of ERMs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Number of SQSs exceeded	Compounds exceeding SQSs	Number of CSLs exceeded	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
22, 170, Dyes Inlet	10		0.26		1	Benzyl Alcohol			100.00		101.00		1.04		27.6	++	894	33	0.58	4	266	364	57	200	7	Pinnixa schmitti	271
																										Amphiodia urtica/periercta complex	196
																										Aphelochaeta sp. N1	181
																										Eudorella (Tridentata) pacifica	92
																										Acila castrensis	32
																										Pholoe sp. N1	24
																										Terebellides californica	11
																										Rochefortia tumida	10
																										Prionospio (Minuspio) light	8
																										Aphelochaeta monilaris	8
22, 171, Dyes Inlet	10		0.26		2	Mercury, Benzyl Alcohol	1	Mercury	101.11		92.00		2.03		30.4	++	1113	39	0.55	4	260	574	48	224	7	Pinnixa schmitti	440
																										Amphiodia urtica/periercta complex	220
																										Eudorella (Tridentata) pacifica	130
																										Terebellides californica	62
																										Prionospio (Minuspio) light	57
																										Aphelochaeta sp. N1	49
																										Rochefortia tumida	37
																										Pholoe sp. N1	37
																										Nephtys cornuta	18
																										Lumbrineris cruzensis	7
24, 176, Shoreline Elliott Bay	5		0.31		4	Mercury, Benzo(g,h,i) perylene, Phenanthrene, Butylbenzyl-phthalate			92.22		82.00	*	2.27		12.5	++	876	113	0.77	22	501	97	255	12	11	Alvania compacta	132
																										Spiochaetopterus costarum	98
																										Parvilucina tenuisculpta	72
																										Dipolydora cardalia	43
																										Mediomastus sp.	36
																										Euphilomedes carcharodonta	32
																										Lumbrineris californiensis	31
																										Prionospio steenstrupi	27
																										Eumida longicornuta	22
																										Caulleriella pacifica	19

Table 33. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Number of ERMs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Number of SQSs exceeded	Compounds exceeding SQSs	Number of CSLs exceeded	Compounds excceding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
25, 179, Shoreline Elliott Bay	13		0.52		1	Benzo(g,h,i) perylene			95.56		81.00	*	25.10		38.8	+++	478	69	0.73	12	254	83	137	0	4	Levinsenia gracilis	70
																										Prionospio steenstrupi	64
																										Axinopsida serricata	62
																										Euphilomedes carcharodonta	52
																										Parvilucina tenuisculpta	43
																										Euphilomedes producta	22
																										Scoletoma luti	9
																										Aricidea (Acmira) lopezi	9
																										Nephtys ferruginea	9
																										Aphelochaeta sp. N1	8
25, 180, Shoreline Elliott Bay	15		0.57		2	Benzo(g,h,i) perylene, Indeno(1,2,3-c,d)pyrene			97.85		68.00	**	17.50		34.4	++	639	77	0.79	19	350	66	215	3	5	Parvilucina tenuisculpta	82
																										Prionospio steenstrupi	79
																										Axinopsida serricata	73
																										Euphilomedes producta	39
																										Aphelochaeta sp. N1	23
																										Scoletoma luti	23
																										Levinsenia gracilis	19
																										Notomastus tenuis	18
																										Solamen columbiana	16
																										Pinnixa schmitti	15
25, 181, Shoreline Elliott Bay	24	1	1.59	Total PCBs	4	Mercury, Benzo(g,h,i) perylene, Total HPAHs, Total PAHs			87.78	*	96.00		17.20		32.8	++	457	85	0.83	27	212	88	142	2	13	Euphilomedes producta	69
																										Axinopsida serricata	55
																										Levinsenia gracilis	19
																										Chaetozone nr. setosa	17
																										Prionospio steenstrupi	17
																										Scoletoma luti	15
																										Macoma carlottensis	12
																										Euclymeninae	12
																										Euphilomedes carcharodonta	11
																										Spiophanes berkeleyorum	10

Table 33. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Number of ERMs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Number of SQSs exceeded	Compounds exceeding SQSs	Number of CSLs exceeded	Compounds excceding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
25, 115, Shoreline Elliott Bay	24		0.83		2	Benzo(g,h,i) perylene, 4-Methylphenol	1	4-Methylphenol	96.97		6.00	**	0.79		144.8	+++	1161	43	0.26	1	1092	9	60	0	0	Aphelochaeta sp. N1	962
																										Lumbrineris californiensis	43
																										Turbonilla sp.	35
																										Scoletoma luti	12
																										Spiochaetopterus costarum	12
																										Alvania compacta	10
																										Armandia brevis	9
																										Notomastus tenuis	9
																										Parvilucina tenuisculpta	7
																										Prionospio sp.	6
26, 182, Shoreline Elliott Bay	24	4	1.36	Mercury, Pyrene, Total LPAHs, Total HPAHs, Total PCBs	4	Mercury, Benzo(g,h,i) perylene, Fluoranthene, Indeno(1,2,3-c,d)pyrene	1	Mercury	97.85		83.00	*	26.47		216.1	+++	571	88	0.79	23	309	37	188	21	16	Axinopsida serricata	115
																										Levinsenia gracilis	73
																										Aricidea (Acmira) lopezi	22
																										Euphilomedes producta	18
																										Scoletoma luti	16
																										Spiophanes berkeleyorum	15
																										Prionospio steenstrupi	14
																										Amphiodia urtica/periercta complex	14
																										Nemocardium centifilosum	14
																										Chaetozone nr. setosa	14
26, 183, Shoreline Elliott Bay	20		0.52		10	Benzo(a) anthracene, Benzo(a)pyrene, Benzo(g,h,i) perylene, Fluoranthene, Fluorene, Indeno(1,2,3-c,d)pyrene, Phenanthrene, Total fluoranthene,	1	Benzo(a)pyrene	100.00		88.00		3.17		107.2	+++	740	105	0.80	23	435	133	159	3	10	Prionospio steenstrupi	79
																										Euphilomedes carcharodonta	65
																										Parvilucina tenuisculpta	61
																										Lumbrineris californiensis	59
																										Axinopsida serricata	53
																										Pinnixa schmitti	27
																										Prionospio (Minuspio) multibranchiata	25
																										Aphelochaeta sp. N1	25
																										Spiochaetopterus costarum	18
																										Scoletoma luti	16

Table 33. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Number of ERMs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Number of SQSs exceeded	Compounds exceeding SQSs	Number of CSLs exceeded	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
26, 184, Shoreline Elliott Bay	22	9	1.31	Anthracene, Total LPAHs, Benzo(a) anthracene, Benzo(a) pyrene, Fluoranthene, Phenanthrene, Pyrene, Total HPAHs, Total PAHs	7	Benzo(a)pyrene, Benzo(g,h,i) perylene, Fluoranthene, Indeno(1,2,3-c,d)pyrene, Phenanthrene, Total HPAHs, Total fluoranthene	4	Fluoranthene, Total Benzo-fluoranthene, Total HPAHs, Total PAHs	103.23		84.00	*	7.90		223.2	+++	731	89	0.79	21	488	57	177	2	7	Lumbrineris californiensis	97
																										Prionospio steenstrupi	82
																										Parvilucina tenuisculpta	77
																										Aphelochaeta sp. N1	39
																										Axinopsida serricata	33
																										Alvania compacta	33
																										Euphilomedes carcharodonta	23
																										Nephtys cornuta	19
																										Spiochaetopterus costarum	17
																										Lumbrineris sp.	15
27, 185, Mid Elliott Bay	7		0.39		1	Bis(2-Ethylhexyl) Phthalate			104.30		120.00		18.20		19.7	++	269	32	0.74	9	106	57	101	1	4	Axinopsida serricata	98
																										Prionospio (Minuspio) light	23
																										Levinsenia gracilis	17
																										Spiophanes berkeleyorum	15
																										Eudorellopsis integra	14
																										Anonyx cf. lilljeborg	12
																										Cossura bansei	10
																										Eudorellopsis longirostris	10
																										Ampharete cf. crassiseta	8
																										Euphilomedes producta	8
27, 186, Mid Elliott Bay	13	1	0.57	Mercury	1	Mercury	1	Mercury	101.08		116.00		34.00		54.9	+++	655	70	0.61	9	169	84	392	3	7	Axinopsida serricata	294
																										Euphilomedes producta	56
																										Parvilucina tenuisculpta	26
																										Euphilomedes carcharodonta	26
																										Levinsenia gracilis	22
																										Prionospio steenstrupi	22
																										Nemocardium centifilosum	18
																										Proclea graffii	17
																										Macoma carlottensis	14
																										Aricidea (Acmira) lopezi	13

Table 33. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Number of ERMs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Number of SQSs exceeded	Compounds exceeding SQSs	Number of CSLs exceeded	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
27, 188, Mid Elliott Bay	23	6	1.47	Benzo(a)pyrene, Phenanthrene, Pyrene, Total LPAHs, Total HPAHs, Total PCBs	6	Mercury, Benzo(g,h,i) perylene, Fluoranthene, Indeno(1,2,3-c,d)pyrene, Benzyl Alcohol, 2,4-Dimethylphenol	2	Mercury, 2,4-Dimethylphenol	105.49		115.00		67.17		152.9	+++	825	67	0.51	5	166	72	563	8	16	Axinopsida serricata	471
																										Euphilomedes producta	51
																										Levinsenia gracilis	40
																										Parvilucina tenuisculpta	37
																										Nemocardium centifilosum	22
																										Aricidea (Acmira) lopezi	18
																										Proclea graffii	17
																										Euphilomedes carcharodonta	13
																										Scoletoma luti	12
																										Chaetozone nr. setosa	9
29, 194, Mid Elliott Bay	23	1	1.05	Dibenzo(a,h,) anthracene, Total PCBs	3	Mercury, Dibenzo(a,h) anthracene, 4-Methylphenol	2	Mercury, 4-Methylphenol	102.15		106.00		62.40		74.1	+++	456	46	0.54	4	184	10	261	0	1	Axinopsida serricata	247
																										Aricidea (Acmira) lopezi	38
																										Levinsenia gracilis	30
																										Spiophanes berkeleyorum	28
																										Prionospio (Minuspio) light	16
																										Scoletoma luti	13
																										Mediomastus sp.	6
																										Microclymene caudata	6
																										Macoma carlottensis	5
																										Cossura pygodactylata	5
29, 196, Mid Elliott Bay	13	1	0.54	Mercury	1	Mercury	1	Mercury	100.00		108.00		55.63		28.6	++	471	42	0.45	3	131	18	320	2	0	Axinopsida serricata	310
																										Aricidea (Acmira) lopezi	29
																										Levinsenia gracilis	27
																										Prionospio (Minuspio) light	12
																										Scoletoma luti	11
																										Spiophanes berkeleyorum	8
																										Heterophoxus affinis	7
																										Cossura bansei	5
																										Nephtys ferruginea	4
																										Mediomastus sp.	4

Table 33. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Number of ERMs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Number of SQSs exceeded	Compounds exceeding SQSs	Number of CSLs exceeded	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
30, 197, West Harbor Island	18	2	0.60	Arsenic, Zinc	4	Arsenic, Acenaphthene, Dibenzofuran, 4-Methylphenol	2	Arsenic, 4-Methylphenol	87.91		62.00	**	2.23		96.6	+++	806	71	0.68	12	394	103	304	1	4	Parvilucina tenuisculpta	261
																										Euphilomedes carcharodonta	89
																										Lumbrineris californiensis	64
																										Prionospio steenstrupi	47
																										Spiochaetopterus costarum	31
																										Aphelochaeta sp. N1	26
																										Mediomastus sp.	26
																										Magelona longicornis	15
																										Heteromastus filobranchus	15
																										Asabellides lineata	14
30, 198, West Harbor Island	22	6	1.26	2-Methylnaphthalene, Acenapththene, Fluorene, Napthalene, Total LPAHs, Total PCBs	6	Acenaphthene, Fluorene, Napthalene, Total LPAHs, Dibenzofuran, 4-Methylphenol	4	Acenaphthene, Napthalene, Dibenzofuran, 4-Methylphenol	101.10		100.00		59.93		132.2	+++	1128	90	0.63	9	259	347	511	0	11	Axinopsida serricata	358
																										Euphilomedes carcharodonta	142
																										Euphilomedes producta	141
																										Parvilucina tenuisculpta	59
																										Rutiderma lomae	41
																										Myriochele heeri	40
																										Prionospio steenstrupi	34
																										Nemocardium centifilosum	26
																										Macoma carlottensis	14
																										Exogone (E.) lourei	14
30, 199, West Harbor Island	22	2	0.96	Total LPAHs, Total PCBs	3	Acenaphthene, Dibenzofuran, 4-Methylphenol	1	4-Methylphenol	90.11		73.00	**	64.80		148.1	+++	1391	84	0.65	10	473	406	495	11	6	Euphilomedes carcharodonta	357
																										Axinopsida serricata	212
																										Parvilucina tenuisculpta	154
																										Aphelochaeta sp. N1	130
																										Spiochaetopterus costarum	43
																										Scoletoma luti	43
																										Astyris gausapata	35
																										Magelona longicornis	35
																										Apistobranchus ornatus	34
																										Euphilomedes producta	33

Table 33. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Number of ERMs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Number of SQSs exceeded	Compounds exceeding SQSs	Number of CSLs exceeded	Compounds excceding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
30, 114, West Harbor Island	21	2	1.34	Benzo(a) pyrene, Total PCBs	2	Benzo(g,h,i) perylene, 4-Methylphenol	1	4-Methylphenol	94.95		86.00		0.79		111.4	+++	1077	47	0.39	2	982	21	73	0	1	Aphelochaeta sp. N1	763
																										Heteromastus filobranchus	60
																										Scoletoma luti	35
																										Cossura pygodactylata	35
																										Axinopsida serricata	23
																										Chaetozone nr. setosa	18
																										Parvilucina tenuisculpta	14
																										Aphelochaeta monilaris	13
																										Alvania compacta	13
																										Euphilomedes carcharodonta	11
31, 200, East Harbor Island	22	1	3.93	Total PCBs	2	1,4-Dichloro-benzene, 4-Methylphenol	1	4-Methylphenol	100.00		68.00	**	25.40		153.5	+++	980	56	0.60	5	802	27	149	0	2	Aphelochaeta sp. N1	352
																										Chaetozone nr. setosa	168
																										Axinopsida serricata	95
																										Scoletoma luti	86
																										Spiochaetopterus costarum	36
																										Prionospio steenstrupi	29
																										Heteromastus filobranchus	21
																										Parvilucina tenuisculpta	19
																										Euphilomedes carcharodonta	15
																										Lumbrineris californiensis	14
31, 201, East Harbor Island	23	1	1.60	Total PCBs	2	Bis(2-Ethylhexyl) Phthalate, 4-Methylphenol	1	4-Methylphenol	92.31		66.00	**	3.13		135.3	+++	1415	57	0.39	2	1281	37	95	0	2	Aphelochaeta sp. N1	955
																										Scoletoma luti	140
																										Axinopsida serricata	60
																										Aphelochaeta monilaris	44
																										Levinsenia gracilis	18
																										Spiochaetopterus costarum	15
																										Parvilucina tenuisculpta	13
																										Boccardiella hamata	12
																										Exogone (E.) lourei	12
																										Heteromastus filobranchus	10

Table 33. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Number of ERMs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Number of SQSs exceeded	Compounds exceeding SQSs	Number of CSLs exceeded	Compounds excceding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
31, 202, East Harbor Island	25	1	2.16	Total PCBs	1	4-Methylphenol	1	4-Methylphenol	90.11	*	100.00		7.67		133.2	+++	1572	42	0.45	3	891	23	657	0	1	Axinopsida serricata	589
																										Aphelochaeta sp. N1	514
																										Scoletoma luti	282
																										Aphelochaeta monilaris	22
																										Macoma sp.	18
																										Alvania compacta	17
																										Heteromastus filobranchus	13
																										Macoma carlottensis	13
																										Chaetozone nr. setosa	11
																										Prionospio steenstrupi	10
32, 204, Duwamish	8	1	0.72	Total PCBs	2	Bis(2-Ethylhexyl) Phthalate, 4-Methylphenol	1	4-Methylphenol	92.31		103.00		3.33		77	+++	1155	52	0.37	2	1002	31	117	1	4	Aphelochaeta sp. N1	814
																										Scoletoma luti	58
																										Macoma sp.	47
																										Nutricola lordi	35
																										Capitella capitata hyperspecies	33
																										Euphilomedes carcharodonta	27
																										Armandia brevis	23
																										Euchone limnicola	14
																										Heteromastus filobranchus	13
																										Alvania compacta	11
32, 205, Duwamish	20	1	2.01	Total PCBs	5	Benzo(g,h,i) perylene, Indeno(1,2,3-c,d)pyrene, Butylbenzyl-phthalate, 4-Methylphenol, Penta-chlorophenol	1	4-Methylphenol	100.81		94.00		3.57		46.9	+++	1561	65	0.45	3	1314	17	226	1	3	Aphelochaeta sp. N1	660
																										Scoletoma luti	455
																										Nutricola lordi	98
																										Cossura pygodactylata	90
																										Axinopsida serricata	77
																										Macoma sp.	12
																										Macoma carlottensis	10
																										Lanassa venusta	9
																										Aphelochaeta sp.	8
																										Heteromastus filobranchus	8

Amphipod: * mean % survival significantly less than CLIS controls ($p<0.05$); ** mean % survival significantly less than CLIS controls ($p<0.05$) and less than 80% of CLIS controls
Urchin fertilization: * mean % fertilization significantly different from controls and exceeds minimum significant difference (Dunnett's t-test: * = $\alpha < 0.05$, MSD = 15.5%; or ** = $\alpha < 0.01$, MSD = 19.0%)

Microtox EC50: ^ = mean EC50<0.51 mg/ml determined as the 80% lower prediction limit (LPL) with the lowest (i.e., most toxic) samples removed, but >0.06 mg/ml determined as the 90% lower prediction limit (LPL) earlier in this report.

Cytochrome P 450 HRGS as µgB[a]P/g: ++ = value >11.1 benzo[a]pyrene equivalents (ug/g sediment) determined as the 80% upper prediction limit (UPL); +++ = value >37.1 benzo[a]pyrene equivalents (µg/g sediment) determined as the 90% upper prediction limit (UPL)

Table 34. Triad results for 1998 central Puget Sound stations with no significant results for both chemistry and toxicity parameters.

Stratum, Sample, Location	Number of ERLs exceeded	Number of ERMs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Number of SQSs exceeded	Compounds exceeding SQSs	Number of CSLs exceeded	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
2, 110, Port Townsend			0.06						97.96		116.73		422.71		44.67		1.2		410	68	0.79	18	96	67	224	17	6	Nutricola lordi	97
																												Rochefortia tumida	26
																												Tellina modesta	22
																												Parvilucina tenuisculpta	19
																												Chaetozone nr. setosa	18
																												Gammaropsis thompsoni	17
																												Scoloplos armiger	16
																												Tellina nuculoides	14
																												Dendraster excentricus	14
																												Galathowenia oculata	9
4, 112, South Admiralty Inlet			0.08						96.94		111.98		29.65	**	3.13		4.3		2325	176	0.54	17	758	1349	133	26	59	Erichthonius rubricornis	1198
																												Microclymene caudata	135
																												Oligochaeta	57
																												Pholoides aspera	40
																												Mediomastus sp.	39
																												Maldanidae sp.	31
																												Exogone (E.) lourei	31
																												Ampelisca sp. A	28
																												Crepipatella dorsata	28
																												Cirratulus spectabilis	24
4, 116, South Admiralty Inlet			0.06						101.02		118.40		223.03		23.57		0.4		554	53	0.71	8	95	197	254	3	5	Rhepoxynius daboius	94
																												Pinnixa schmitti	85
																												Tellina modesta	82
																												Axinopsida serricata	49
																												Rochefortia tumida	36
																												Nutricola lordi	34
																												Parvilucina tenuisculpta	28
																												Scoloplos armiger	24
																												Leitoscoloplos pugettensis	16
																												Mediomastus sp.	10
4, 117, South Admiralty Inlet	1		0.06						95.92		117.92		176.03		18.60		0.6		227	50	0.81	15	78	60	84	0	5	Nutricola lordi	53
																												Photis bifurcata	22
																												Orchomene cf. pinguis	14
																												Scoloplos armiger	12
																												Leitoscoloplos pugettensis	10
																												Dipolydora socialis	10
																												Pinnixa schmitti	9
																												Parvilucina tenuisculpta	9
																												Rochefortia tumida	7
																												Rhepoxynius abronius	6

Table 34. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Number of ERMs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Number of SQSs exceeded	Compounds exceeding SQSs	Number of CSLs exceeded	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
5, 119, Posses-sion Sound			0.06						97.92		117.68		291.48		30.80		0.7		197	35	0.73	8	86	85	17	1	8	Rhepoxynius daboius	60
																												Spiophanes bombyx	32
																												Scoloplos armiger	18
																												Pinnixa schmitti	16
																												Prionospio steenstrupi	9
																												Tellina modesta	6
																												Carinoma mutabilis	5
																												Pholoe sp. N1	5
																												Spiophanes berkeleyorum	5
																												Nephtys ferruginea	4
5, 120, Posses-sion Sound	1		0.07						102.08		117.92		220.19		23.27		0.5		201	33	0.73	6	92	80	29	0	0	Spiophanes bombyx	49
																												Pinnixa schmitti	44
																												Rhepoxynius daboius	25
																												Tellina modesta	13
																												Prionospio steenstrupi	12
																												Orchomene pacificus	8
																												Leitoscoloplos pugettensis	5
																												Nephtys ferruginea	4
																												Prionospio (Minuspio) light	3
																												Cheirimedeia zotea	3
6, 121, Central Basin			0.06						89.01		115.54		82.02		8.67		2.1		1272	60	0.58	5	107	677	475	0	13	Euphilomedes carcharodonta	517
																												Solamen columbiana	194
																												Lirobittium sp.	101
																												Cheirimedeia cf. macrocarpa	89
																												Parvilucina tenuisculpta	71
																												Nutricola lordi	41
																												Spiophanes bombyx	24
																												Rochefortia tumida	17
																												Orchomene cf. pinguis	15
																												Rhepoxynius abronius	15
7, 124, Port Madison			0.07						105.68		117.44		26.50	**	2.80		3.2		729	73	0.73	12	182	212	138	190	7	Euphilomedes carcharodonta	117
																												Amphiodia sp.	106
																												Amphiodia urtica/periercta complex	78
																												Pinnixa schmitti	59
																												Parvilucina tenuisculpta	49
																												Axinopsida serricata	34
																												Mediomastus sp.	24
																												Euphilomedes producta	20
																												Polycirrus californicus	19
																												Rhepoxynius boreovariatus	16

Table 34. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Number of ERMs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Number of SQSs exceeded	Compounds exceeding SQSs	Number of CSLs exceeded	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
7, 125, Port Madison			0.08						101.14		116.97		28.08	**	2.97		4.7		852	87	0.76	14	280	319	135	103	15	Euphilomedes carcharodonta	123
																												Euphilomedes producta	89
																												Amphiodia urtica/periercta complex	74
																												Polycirrus californicus	64
																												Pinnixa schmitti	46
																												Rhepoxynius boreovariatus	43
																												Mediomastus sp.	41
																												Axinopsida serricata	28
																												Amphiodia sp.	25
																												Parvilucina tenuisculpta	25
7, 126, Port Madison			0.05						98.86		116.97		460.88		48.70		2.4		637	93	0.78	18	219	176	130	101	11	Amphiodia urtica/periercta complex	83
																												Rhepoxynius boreovariatus	69
																												Euphilomedes carcharodonta	46
																												Polycirrus californicus	45
																												Axinopsida serricata	38
																												Euphilomedes producta	35
																												Polycirrus sp.	31
																												Parvilucina tenuisculpta	31
																												Pinnixa schmitti	16
																												Amphiodia sp.	15
10, 133, Central Sound			0.07						97.80		105.44		114.83		12.13		8.7		531	77	0.73	16	124	178	179	32	18	Axinopsida serricata	116
																												Euphilomedes producta	67
																												Euphilomedes carcharodonta	63
																												Parvilucina tenuisculpta	37
																												Amphiodia urtica/periercta complex	23
																												Pinnixa occidentalis	17
																												Mediomastus sp.	12
																												Rhepoxynius bicuspidatus	10
																												Aricidea (Allia) ramosa	9
																												Amphiodia sp.	8

Table 34. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Number of ERMs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Number of SQSs exceeded	Compounds exceeding SQSs	Number of CSLs exceeded	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
12, 141, East Passage			0.06						80.00		102.45		606.62		64.10		5.8		265	79	0.91	33	177	38	33	3	14	Pionosyllis uraga	23
																												Lumbrineris californiensis	19
																												Nicomache lumbricalis	11
																												Pholoides aspera	9
																												Demonax rugosus	9
																												Aricidea (Acmira) lopezi	8
																												Tritella pilimana	7
																												Pista elongata	7
																												Syllis (Ehlersia) heterochaeta	7
																												Nemocardium centifilosum	6
13, 142, Liberty Bay	4		0.13						94.32		105.44		49.84	**	5.27		16.7		325	26	0.70	6	109	102	4	107	3		
																												Amphiodia urtica/periercta complex	96
																												Pinnixa schmitti	79
																												Aphelochaeta sp. N1	25
																												Nephtys cornuta	22
																												Eudorella (Tridentata) pacifica	16
																												Pholoe sp. N1	15
																												Spiophanes berkeleyorum	15
																												Amphiodia sp.	11
																												Terebellides californica	7
																												Heteromastus filobranchus	5
14, 145, Keyport			0.04						105.68		106.08		26.81	**	2.83		2.5		354	48	0.87	16	179	61	107	3	4	Aphelochaeta sp. N1	34
																												Nutricola lordi	31
																												Leitoscoloplos pugettensis	24
																												Scoloplos acmeceps	22
																												Ampharete labrops	21
																												Alvania compacta	19
																												Scoletoma luti	16
																												Rochefortia tumida	16
																												Protomedeia grandimana	14
																												Mediomastus sp.	13
14, 147, Keyport			0.07						98.86		105.66		53.31	**	5.63		5.6		543	85	0.75	17	354	25	149	4	11	Aphelochaeta sp. N1	124
																												Ampharete labrops	58
																												Alvania compacta	36
																												Nutricola lordi	30
																												Scoloplos acmeceps	28
																												Leitoscoloplos pugettensis	28
																												Mediomastus sp.	15
																												Glycinde polygnatha	13
																												Odostomia sp.	12
																												Astyris gausapata	12

Table 34. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Number of ERMs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Number of SQSs exceeded	Compounds exceeding SQSs	Number of CSLs exceeded	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
15, 149, NW Bain-bridge Island			0.04						95.45		103.95		10.28	**	1.09		6.6		810	73	0.67	13	204	112	466	13	15	Alvania compacta	290
																												Rochefortia tumida	93
																												Phyllochaetopterus prolifica	61
																												Heptacarpus stimpsoni	52
																												Macoma yoldiformis	23
																												Aoroides intermedius	20
																												Dipolydora socialis	14
																												Caulleriella pacifica	11
																												Tellina modesta	11
																												Scoloplos sp.	11
15, 150, NW Bain-bridge Island			0.07						93.18		105.87		11.67	**	1.23		9.3		435	44	0.70	7	136	17	127	148	7	Amphiodia urtica/periercta complex	89
																												Acteocina culcitella	84
																												Amphiodia sp.	55
																												Pholoe sp. N1	55
																												Acila castrensis	24
																												Lumbrineris cruzensis	14
																												Pinnixa occidentalis	12
																												Heteromastus filobranchus	12
																												Spiophanes berkeleyorum	9
																												Cossura pygodactylata	6
6, 152, SW Bain-bridge Island			0.08						98.95		105.44		43.53	**	4.60		7.6		859	87	0.69	15	165	122	475	86	11	Acila castrensis	289
																												Euphilomedes carcharodonta	70
																												Amphiodia urtica/periercta complex	50
																												Axinopsida serricata	33
																												Ennucula tenuis	27
																												Macoma sp.	26
																												Amphiodia sp.	23
																												Odostomia sp.	23
																												Alvania compacta	18
																												Astyris gausapata	18
17, 154, Rich Passage			0.04						97.89		104.80		73.82		7.80		1.9		659	99	0.08	23	199	41	395	5	19	Nutricola lordi	138
																												Alvania compacta	75
																												Tellina modesta	44
																												Parvilucina tenuisculpta	24
																												Macoma yoldiformis	22
																												Lirularia lirulata	22
																												Spiochaetopterus costarum	20
																												Lumbrineris californiensis	14
																												Rochefortia tumida	14
																												Protodorvillea gracilis	12

Table 34. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Number of ERMs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Number of SQSs exceeded	Compounds exceeding SQSs	Number of CSLs exceeded	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
17, 155, Rich Passage			0.04						98.95		105.66		191.80		20.27		1.6		951	68	0.61	6	93	138	709	0	11	Nutricola lordi	290
																												Tellina modesta	220
																												Euphilomedes carcharodonta	79
																												Rochefortia tumida	57
																												Parvilucina tenuisculpta	57
																												Protomedeia grandimana	23
																												Euclymeninae	18
																												Lirobittium sp.	15
																												Turbonilla sp.	13
																												Astyris gausapata	12
17, 156, Rich Passage			0.07						97.89		105.02		285.49		30.17		10		573	102	0.82	24	234	189	105	19	26	Pinnixa occidentalis	64
																												Euphilomedes carcharodonta	62
																												Rochefortia tumida	37
																												Mediomastus sp.	29
																												Astyris gausapata	23
																												Prionospio (Minuspio) light	22
																												Rhepoxynius daboius	21
																												Syllis (Ehlersia) hyperion	20
																												Dipolydora socialis	17
																												Amphiodia urtica/periercta complex	15
21, 166, Port Washington Narrows			0.06						104.44		111.00		32.18	**	3.40		6.5		651	85	0.79	20	196	162	270	5	18	Euphilomedes carcharodonta	92
																												Alvania compacta	79
																												Nutricola lordi	58
																												Aphelochaeta sp. N1	29
																												Rochefortia tumida	28
																												Phyllochaetopterus prolifica	28
																												Lumbrineris californiensis	24
																												Astyris gausapata	24
																												Nassarius mendicus	19
																												Westwoodilla caecula	15
22, 169, Dyes Inlet			0.05						101.11		94.00		38.80	**	4.10		3.6		1574	74	0.65	9	1123	248	179	17	7	Phyllochaetopterus prolifica	455
																												Circeis sp.	240
																												Aphelochaeta sp. N1	137
																												Caprella mendax	122
																												Rochefortia tumida	74
																												Scoletoma luti	53
																												Pinnixa schmitti	45
																												Lumbrineris californiensis	39
																												Astyris gausapata	31
																												Euclymene cf. zonalis	27

Table 34. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Number of ERMs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Number of SQSs exceeded	Compounds exceeding SQSs	Number of CSLs exceeded	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
23, 175, Outer Elliott Bay			0.07						97.78		96.00		49.53	**	5.23		3.3		631	137	0.89	48	352	114	114	28	23	Euphilomedes carcharodonta	36
																												Dipolydora socialis	27
																												Prionospio steenstrupi	24
																												Mediomastus sp.	21
																												Pholoides aspera	18
																												Lumbrineris californiensis	17
																												Nemocardium centifilosum	16
																												Axinopsida serricata	15
																												Parvilucina tenuisculpta	14
																												Pinnixa schmitti	14
24, 178, Shoreline Elliott Bay			0.14						101.11		106.00		821.77		86.83		10.7		343	80	0.78	21	179	104	56	1	3	Euphilomedes carcharodonta	70
																												Prionospio steenstrupi	38
																												Magelona longicornis	27
																												Pinnixa schmitti	19
																												Exogone (E.) lourei	14
																												Spiochaetopterus costarum	13
																												Parvilucina tenuisculpta	11
																												Solamen columbiana	10
																												Lyonsia californica	6
																												Nephtys ferruginea	6

Amphipod: * mean % survival significantly less than CLIS controls ($p<0.05$); ** mean % survival significantly less than CLIS controls ($p<0.05$) and less than 80% of CLIS controls
Urchin fertilization: * mean % fertilization significantly different from controls and exceeds minimum significant difference (Dunnett's t-test: * $=\alpha < 0.05$, MSD = 15.5%; or ** $= \alpha < 0.01$, MSD = 19.0%)

Microtox EC50: ^ = mean EC50<0.51 mg/ml determined as the 80% lower prediction limit (LPL) with the lowest (i.e., most toxic) samples removed, but >0.06 mg/ml determined as the 90% lower prediction limit (LPL) earlier in this report.

Cytochrome P450 HRGS as µgB[a]P/g: ++ = value >11.1 benzo[a]pyrene equivalents (ug/g sediment) determined as the 80% upper prediction limit (UPL); +++ = value >37.1 benzo[a]pyrene equivalents (µg/g sediment) determined as the 90% upper prediction limit (UPL)

Table 35. Distribution of results in amphipod survival tests (with *A. abdita* only) in northern Puget Sound, central Puget Sound, and in the NOAA/EMAP "national" database.

	National data base (n=2630)		Northern Puget Sound (n=100)	Central Puget Sound (n=100)
Percent control adjusted amphipod survival	Number of samples	Percent of total	Percent of total	Percent of total
≥ 100	734	28	21	44
90-99.9	1237	47	76	48
80-89.9	330	13	3	7
70-79.9	112	4	0	0
60-69.9	55	2	0	0
50-59.9	30	1	0	0
40-49.9	24	1	0	1
30-39.9	27	1	0	0
20-29.9	19	1	0	0
10-19.9	25	1	0	0
0.0-9.9	35	1	0	0

Table 36. Spatial extent of toxicity (km^2 and percentages of total area) in amphipod survival tests performed with solid-phase sediments from 26 U.S. bays and estuaries. Unless specified differently, test animals were *Ampelisca abdita*.

Survey Areas	Year sampled	No. of sediment samples	Total area of survey (km^2)	Amphipod survival: Toxic area (km^2)	Amphipod survival: Pct. of area toxic
Newark Bay	1993	57	13	10.8	85.0%
San Diego Bay*	1993	117	40.2	26.3	65.8%
California coastal lagoons	1994	30	5	2.9	57.9%
Tijuana River*	1993	6	0.3	0.2	56.2%
Long Island Sound	1991	60	71.9	36.3	50.5%
Hudson-Raritan Estuary	1991	117	350	133.3	38.1%
San Pedro Bay*	1992	105	53.8	7.8	14.5%
Biscayne Bay	1995/1996	226	484.2	62.3	12.9%
Boston Harbor	1993	55	56.1	5.7	10.0%
Delaware Bay	1997	73	2346.8	145.4	6.2%
Savannah River	1994	60	13.1	0.2	1.2%
St. Simons Sound	1994	20	24.6	0.1	0.4%
Tampa Bay	1992/1993	165	550	0.5	0.1%
central Puget Sound	**1998**	**100**	**731.7**	**1.0**	**0.1%**
Pensacola Bay	1993	40	273	0.04	0.0%
Galveston Bay	1996	75	1351.1	0	0.0%
northern Puget Sound	**1997**	**100**	**773.9**	**0**	**0.0%**
Choctawhatchee Bay	1994	37	254.5	0	0.0%
Sabine Lake	1995	66	245.9	0	0.0%
Apalachicola Bay	1994	9	187.6	0	0.0%
St. Andrew Bay	1993	31	127.2	0	0.0%
Charleston Harbor	1993	63	41.1	0	0.0%
Winyah Bay	1993	9	7.3	0	0.0%
Mission Bay*	1993	11	6.1	0	0.0%
Leadenwah Creek	1993	9	1.7	0	0.0%
San Diego River*	1993	2	0.5	0	0.0%
Cumulative National estuarine average based upon data collected through:					
•1997		1543	7278.8	431.8	5.9%

* tests performed with *Rhepoxynius abronius*

Table 37. Spatial extent of toxicity (km^2 and percentages of total area) in sea urchin fertilization tests performed with 100% sediment pore waters from 23 U. S. bays and estuaries. Unless specified differently, tests performed with *Arbacia punctulata*.

Survey areas	Year sampled	No. of sediment samples	Total area of survey (km^2)	Urchin fertilization in 100% pore waters: Toxic area (km^2)	Urchin fertilization in 100% pore waters: Pct. of area toxic
San Pedro Bay[a]	1992	105	53.8	52.6	97.7%
Tampa Bay	1992/1993	165	550	463.6	84.3%
San Diego Bay[b]	1993	117	40.2	25.6	76.0%
Mission Bay[b]	1993	11	6.1	4	65.9%
Tijuana River[b]	1993	6	0.3	0.2	56.2%
San Diego River[b]	1993	2	0.5	0.3	52.0%
Biscayne Bay	1995/1996	226	484.2	229.5	47.4%
Choctawhatchee Bay	1994	37	254.5	113.1	44.4%
California coastal lagoons	1994	30	5	2.1	42.7%
Winyah Bay	1993	9	7.3	3.1	42.2%
Apalachicola Bay	1994	9	187.6	63.6	33.9%
Galveston Bay	1996	75	1351.1	432	32.0%
Charleston Harbor	1993	63	41.1	12.5	30.4%
Savannah River	1994	60	13.1	2.42	18.4%
Delaware Bay	1997	73	2346.8	247.5	10.5%
Boston Harbor	1993	55	56.1	3.8	6.6%
Sabine Lake	1995	66	245.9	14	5.7%
Pensacola Bay	1993	40	273	14.4	5.3%
northern Puget Sound[c]	**1997**	**100**	**773.9**	**40.6**	**5.2%**
St. Simons Sound	1994	20	24.6	0.7	2.6%
St. Andrew Bay	1993	31	127.2	2.3	1.8%
central Puget Sound[C]	**1998**	**100**	**731.7**	**5.1**	**0.7%**
Leadenwah Creek	1993	9	1.7	0	0.0%
Cumulative National estuarine average based upon data collected through:					
•1997		1309	6837.8	1728	25.3%

[a] Tests performed for embryological development of *Haliotis rufescens*
[b] Tests performed for embryological development of *Strongylocentrotus purpuratus*
[c] Tests performed for fertilization success of *S. purpuratus*

Table 38. Spatial extent of toxicity (km^2 and percentages of total area) in microbial bioluminescence tests performed with solvent extracts of sediments from 19 U. S. bays and estuaries.

Survey areas	Year sampled	No. of sediment samples	Total area of survey (km^2)	Microbial bioluminescence: Toxic area (km^2)	Microbial bioluminescence: Pct. of area toxic
Choctawhatchee Bay	1994	37	254.47	254.5	100.0%
St. Andrew Bay	1993	31	127.2	127	100.0%
Apalachicola Bay	1994	9	187.6	186.8	99.6%
Pensacola Bay	1993	40	273	262.8	96.4%
Galveston Bay	1996	75	1351.1	1143.7	84.6%
Sabine Lake	1995	66	245.9	194.2	79.0%
Winyah Bay	1993	9	7.3	5.13	70.0%
Long Island Sound	1991	60	71.86	48.8	67.9%
Savannah River	1994	60	13.12	7.49	57.1%
Biscayne Bay	1995/1996	226	484.2	248.4	51.3%
St. Simons Sound	1994	20	24.6	11.4	46.4%
Boston Harbor	1993	55	56.1	25.8	44.9%
Charleston Harbor	1993	63	41.1	17.6	42.9%
Hudson-Raritan Estuary	1991	117	350	136.1	38.9%
Leadenwah Creek	1993	9	1.69	0.34	20.1%
Delaware Bay[A]	1997	73	2346.8	114	4.9%
northern Puget Sound [A]	**1997**	**100**	**773.9**	**9.1**	**1.2%**
Tampa Bay	1992/1993	165	550	0.6	0.1%
central Puget Sound [A]	**1998**	**100**	**731.7**	**0**	**0.0%**
Cumulative National estuarine average based upon data collected through:					
•1997		1215	7160	2802.4	39.1%

[A] Critical value of <0.51 mg/mL

Table 39. Spatial extent of toxicity (km^2 and percentages of total area) in cytochrome P450 HRGS tests performed with solvent extracts of sediments from 8 U. S. bays and estuaries.

Survey areas	Year sampled	No. of sediment samples	Total area of survey (km^2)	Cytochrome P450 HRGS (>11.1 µg/g)		Cytochrome P450 HRGS (>37.1 µg/g)	
				Toxic area (km^2)	PCT. of area toxic	Toxic area (km^2)	PCT. of area toxic
northern Chesapeake Bay	1998	63	2265.0	1127.3	49.8	633.9	28.0
Delaware Bay	1997	73	2346.8	145.2	6.2	80.5	3.4
central Puget Sound	**1998**	**100**	**731.7**	**237.1**	**32.3**	**23.7**	**3.2**
Sabine Lake	1995	65	245.9	6.7	2.7	1.7	0.7
northern Puget Sound	**1997**	**100**	**773.9**	**20.1**	**2.6**	**0.2**	**0.03**
Southern Cal. Estuaries	1994	30	5.0	2.3	46.8	0.0	0.0
Biscayne Bay, 1996	1996	121	271.4	8.8	3.3	0.0	0.0
Galveston Bay	1996	75	1351.5	56.7	4.2	0.0	0.0
Cumulative national estuarine averages based upon data collected through:							
•1997		627	8023.5	1604.2	20.0	740	9.2

Table 40. Percentages of two Puget Sound study areas with indices of degraded sediments based upon the sediment quality triad of data.

Indices of sediment quality	1997 Northern Puget Sound (total area: 773.9km^2)	1998 Central Puget Sound (total area: 731.7km^2)
toxicity, chemical contamination, altered benthos		
Number of stations:	10	18
area (km^2):	10.3	8.1
% of total study area:	1.3	1.1
toxicity, chemical contamination, diverse benthos		
Number of stations:	16	18
area (km^2):	81.7	91.6
% of total study area:	10.6	12.5
mixed toxicity and chemical results, diverse benthos		
Number of stations:	53	39
area (km^2):	530.2	272.6
% of total study area:	68.5	37.3
no toxicity or chemical contamination, diverse benthos		
Number of stations:	21	25
area (km^2):	151.7	359.3
% of total study area:	19.6	49.1

Appendix A

Detected chemicals from central Puget Sound sediment samples in the SEDQUAL database exceeding Washington State Sediment Quality Standards (SQS) and Puget Sound Marine Sediment Cleanup Screening Levels(CSL).

Appendix A. Detected chemicals from central Puget Sound sediment samples in the SEDQUAL database exceeding Washington State Sediment Quality Standards (SQS) and Puget Sound Marine Sediment Cleanup Screening Levels (CSL).

Chemical Contaminant	SQS Sample location (No. of samples)	SQS value	CSL Sample location (No. of samples)	CSL value
1,2,4-Trichlorobenzene	Central Basin (2), Dogfish Bay (1), Duwamish River (3), East Waterway (2), Elliott Bay (1), Liberty Bay (1)	0.81	Central Basin (1), Dogfish Bay (1), Duwamish River (3), East Waterway (1), Elliott Bay (1), Liberty Bay (1)	1.8
1,2-Dichlorobenzene	Duwamish River (3), Eagle Harbor (2), North Harbor Island (1)	2.3	Duwamish River (3), Eagle Harbor (2), North Harbor Island (1)	2.3
1,4-Dichlorobenzene	Dogfish Bay (2), Duwamish River (29), Dyes Inlet (1), East Waterway (6), Elliott Bay (9), Liberty Bay (1), Point Pully (1), Sinclair Inlet (4), West Waterway (2)	3.1	Dogfish Bay (2), Duwamish River (18), Dyes Inlet (1), East Waterway (6), Elliott Bay (4), Liberty Bay (1), Point Pully (1), Sinclair Inlet (4), West Waterway (2)	9
2,4-Dimethylphenol	Bainbridge Island (5), Duwamish River (1), Eagle Harbor (6), Elliott Bay (3), North Harbor Island (6), Sinclair Inlet (1), West Waterway (4)	29	Bainbridge Island (5), Duwamish River (1), Eagle Harbor (6), Elliott Bay (3), North Harbor Island (6), Sinclair Inlet (1), West Waterway (4)	29
2-Methylnaphthalene	Alki Beach (1), Central Sound (3), Duwamish River (7), Dyes Inlet (6), Eagle Harbor (6), Elliott Bay (12), Kellogg Island (1), Liberty Bay (1), Magnolia Bluff (3), North Harbor Island (6), Point Pulley (5), Shilshole Bay (2), Sinclair Inlet (4), Port Townsend (3)	38	Central Sound (3), Duwamish River (6), Dyes Inlet (6), Eagle Harbor (6), Elliott Bay (8), Kellogg Island (1), Liberty Bay (1), Magnolia Bluff (1), North Harbor Island (4), Point Pulley (5), Shilshole Bay (2), Sinclair Inlet (4), Port Townsend (3)	64
2-Methylphenol	Duwamish River (1), North Harbor Island (1), Elliott Bay (1), West Point (6)	63	Duwamish River (1), North Harbor Island (1), Elliott Bay (1), West Point (6)	63
4-Methylphenol	Dogfish Bay (1), Duwamish River (5), Dyes Inlet (1), Elliott Bay (4), Kellogg Island (1), Key Port (1), North Harbor Island (1), Sinclair Inlet (1), West Point (2), West Waterway (2) .	670	Dogfish Bay (1), Duwamish River (5), Dyes Inlet (1), Elliott Bay (4), Kellogg Island (1), Key Port (1), North Harbor Island (1), Sinclair Inlet (1), West Point (2), West Waterway (2) .	670

Appendix A. Continued.

Chemical Contaminant	SQS Sample location (No. of samples)	SQS value	CSL Sample location (No. of samples)	CSL value
Acenaphthene	Alki beach (1), Brace Point (1), Central Sound (1), Dogfish Bay (1), Duwamish River (14), Dyes Inlet (5), Eagle Harbor (14), East Waterway (4), Elliott Bay (51), Magnolia Bluff (2), North Harbor Island (17), Point Pulley (2), Shilshole Bay (2), Sinclair Inlet (4), West Point (6), West Waterway (5)	16	Alki beach (1), Brace Point (1), Dogfish Bay (1), Duwamish River (7), Dyes Inlet (5), Eagle Harbor (11), East Waterway (1), Elliott Bay (51), Magnolia Bluff (2), North Harbor Island (8), Point Pulley (2), Shilshole Bay (1), Sinclair Inlet (4), West Point (2), West Waterway (1)	57
Acenaphthylene	Duwamish River (7), Dyes Inlet (7), Eagle Harbor (7), Elliott Bay (10), Magnolia Bluff (4), North Harbor Island (2), Point Pulley (5), Port Townsend (1), Shilshole Bay (1), Sinclair Inlet (5), West Point (2)	66	Duwamish River (7), Dyes Inlet (7), Eagle Harbor (7), Elliott Bay (10), Magnolia Bluff (4), North Harbor Island (2), Point Pulley (5), Port Townsend (1), Shilshole Bay (1), Sinclair Inlet (5), West Point (2)	66
Anthracene	Brace Point (2), Central Sound (4), Duwamish River (7), Dyes Inlet (7), Eagle Harbor (11), East Waterway (2), Elliott Bay (23), Liberty Bay (1), Magnolia Bluff (7), North Harbor Island (5), Point Pulley (7), Port Townsend (5), Shilshole Bay (3), Sinclair Inlet (7), Vashon Island (1), West Point (3)	220	Brace Point (2), Central Sound (4), Duwamish River (7), Dyes Inlet (7), Eagle Harbor (9), Elliott Bay (4), Liberty Bay (1), Magnolia Bluff (7), North Harbor Island (5), Point Pulley (7), Port Madison (2), Port Townsend (5), Shilshole Bay (3), Sinclair Inlet (7), Vashon Island (1), West Point (3)	1200
Arsenic	Duwamish River (4), East Waterway (1), Elliott Bay (15), Kellogg Island (2), North Harbor Island (8), Sinclair Inlet (7), West Waterway (11)	57	Duwamish River (3), East Waterway (1), Elliott Bay (15), Kellogg Island (2), North Harbor Island (8), Sinclair Inlet (7), West Waterway (11)	93
Benzo(a)anthracene	Alki Beach (1), Brace Point (2), Central Sound (5), Dogfish Bay (1), Duwamish River (10), Dyes Inlet (7), Eagle Harbor (16), East Waterway (3), Elliott Bay (62), Jefferson Head (1), Liberty Bay (2), Magnolia Bluff (9), North Harbor Island (14), Point Pulley (7), Port Madison (4), Port Townsend (6), Richmond Beach (2), Seahurst Passage (1), Shilshole Bay (6), Sinclair Inlet (8), Vashon Island (2), West Point (14), West Waterway (10)	110	Brace Point (2), Central Sound (5), Dogfish Bay (1), Duwamish River (9), Dyes Inlet (7), Eagle Harbor (12), Elliott Bay (34), Jefferson Head (1), Liberty Bay (2), Magnolia Bluff (7), North Harbor Island (5), Point Pulley (7), Port Madison (4), Port Townsend (6), Richmond Beach (2), Seahurst Passage (1), Shilshole Bay (6), Sinclair Inlet (7), Vashon Island (2), West Point (7), West Waterway (1)	270

Appendix A. Continued.

Chemical Contaminant	SQS Sample location (No. of samples)	SQS value	CSL Sample location (No. of samples)	CSL value
Benzo(a)pyrene	Alki Beach (1), Brace Point (2), Central Sound (5), Dogfish Bay (1), Duwamish River (12), Dyes Inlet (8), Eagle Harbor (16), East Waterway (2), Elliott Bay (66), Liberty Bay (2), Magnolia Bluff (9), North Harbor Island (14), Point Pulley (7), Port Madison (4), Port Townsend (6), Richmond Beach (2), Seahurst Passage (1), Shilshole Bay (6), Sinclair Inlet (7), Vashon Island (1), West Point (19), West Waterway (6)	99	Brace Point (2), Central Sound (5), Duwamish River (8), Dyes Inlet (8), Eagle Harbor (9), Elliott Bay (66), Liberty Bay (2), Magnolia Bluff (7), North Harbor Island (5), Point Pulley (7), Port Madison (4), Port Townsend (6), Richmond Beach (2), Seahurst Passage (1), Shilshole Bay (6), Sinclair Inlet (7), Vashon Island (1), West Point (12), West Waterway (1)	210
Benzo(g,h,i)perylene	Alki Beach (2), Brace Point (2), Central Basin (5), Duwamish River (17), Dyes Inlet (8), Eagle Harbor (16), East Waterway (4), Elliott Bay (70), Liberty Bay (2), Magnolia Bluff (9), North Harbor Island (15), Point Pulley (6), Port Madison (2), Port Townsend (5), Richmond Beach (1), Seahurst Passage (1), Shilshole Bay (3), Sinclair Inlet (6), Vashon Island (1), West Point (18), West Waterway (17)	31	Alki Beach (1), Brace Point (2), Central Basin (3), Duwamish River (10), Dyes Inlet (7), Eagle Harbor (8), East Waterway (4), Elliott Bay (42), Liberty Bay (2), Magnolia Bluff (6), North Harbor Island (7), Point Pulley (6), Port Madison (2), Port Townsend (3), Richmond Beach (1), Seahurst Passage (1), Shilshole Bay (3), Sinclair Inlet (5), Vashon Island (1), West Point (15), West Waterway (3)	78
Benzoic acid	Alki Point (1), Dogfish Bay (1), Duwamish River (8), Elliott Bay (13), Kellogg Island (1), Liberty Bay (2), Sinclair Inlet (2), West Point (22)	650	Alki Point (1), Duwamish River (8), Elliott Bay (13), Kellogg Island (1), Liberty Bay (2), Sinclair Inlet (2), West Point (22)	650
Benzyl alcohol	Duwamish River (1), East Waterway (1), Elliott Bay (2), Sinclair Inlet (1), West Point (5), West Waterway (2)	57	Duwamish River (1), East Waterway (1), Elliott Bay (2), Sinclair Inlet (1), West Point (5), West Waterway (2)	73

Appendix A. Continued.

Chemical Contaminant	SQS Sample location (No. of samples)	SQS value	CSL Sample location (No. of samples)	CSL value
Bis(2-ethylhexyl) phthalate	Brace Point (2), Central Sound (3), Dogfish Bay (4), Duwamish River (86), Dyes Inlet (10), Eagle Harbor (4), East Passage (1), East Waterway (5), Elliott Bay (43), Kellogg Island (1), Key Port (11), Liberty Bay (12), Magnolia Bluff (4), North Harbor Island (7), Point Pulley (5), Port Madison (3), Port Townsend (3), Rich Passage (1), Richmond Beach (1), Seahurst Passage (1), Shilshole Bay (4), Sinclair Inlet (19), Useless Bay (1), Vashon Island (1), West Waterway (11)	47	Brace Point (2), Central Sound (3), Dogfish Bay (3), Duwamish River (58), Dyes Inlet (7), Eagle Harbor (4), East Passage (1), East Waterway (3), Elliott Bay (22), Key Port (8), Liberty Bay (11), Magnolia Bluff (4), North Harbor Island (6), Point Pulley (5), Port Madison (3), Port Townsend (3), Rich Passage (1), Richmond Beach (1), Seahurst Passage (1), Shilshole Bay (4), Sinclair Inlet (19), Vashon Island (1), West Waterway (6)	78
Butyl benzyl phthalate	Alki Point (2), Blakely Harbor (2), Central Sound (1), Duwamish River (58), Dyes Inlet (7), Eagle Harbor (6), East Waterway (9), Elliott Bay (34), Kellogg Island (1), Magnolia Bluff (6), North Harbor Island (10), Point Pulley (2), Bainbridge Island (1), Shilshole Bay (1), Sinclair Inlet (14), West Point (9), West Waterway (9), Williams Point (2)	4.9	Central Sound (1), Duwamish River (4), Dyes Inlet (5), East Waterway (3), Elliott Bay (5), Magnolia Bluff (2), North Harbor Island (10), Point Pulley (2), Shilshole Bay (1), Sinclair Inlet (5), West Point (1)	64
Cadmium	Duwamish River (13), East Waterway (14), Elliott Bay (18), Kellogg Island (15), North Harbor Island (17), Sinclair Inlet (8), West Waterway (43)	5.1	Duwamish River (10), East Waterway (12), Elliott Bay (11), Kellogg Island (11), North Harbor Island (7), Sinclair Inlet (1), West Waterway (31)	6.7
Chromium	Duwamish River (3), Elliott Bay (5), West Waterway (2)	260	Duwamish River (3), Elliott Bay (4), West Waterway (2)	270

Appendix A. Continued.

Chemical Contaminant	SQS Sample location (No. of samples)	SQS value	CSL Sample location (No. of samples)	CSL value
Chrysene	Alki Beach (1), Brace Point (3), Central Sound (5), Duwamish River (13), Dyes Inlet (7), Eagle Harbor (19), East Waterway (7), Elliott Bay (80), Jefferson Head (1), Liberty Bay (2), Magnolia Bluff (10), North Harbor Island (19), Point Pulley (7), Port Madison (4), Port Townsend (8), Richmond Beach (2), Seahurst Passage (2), Shilshole Bay (6), Sinclair Inlet (9), Vashon Island (2), West Point (22), West Waterway (22)	110	Brace Point (3), Central Sound (4), Duwamish River (7), Dyes Inlet (7), Eagle Harbor (12), East Waterway (1), Elliott Bay (26), Jefferson Head (1), Liberty Bay (2), Magnolia Bluff (7), North Harbor Island (3), Point Pulley (7), Port Madison (4), Port Townsend (6), Richmond Beach (2), Seahurst Passage (2), Shilshole Bay (6), Sinclair Inlet (7), Vashon Island (2), West Waterway (8)	460
Copper	Alki Beach (1), Duwamish River (1), Dyes Inlet (1), East Waterway (1), Elliott Bay (18), North Harbor Island (16), Sinclair Inlet (13), West Waterway (8)	390	Alki Beach (1), Duwamish River (1), Dyes Inlet (1), East Waterway (1), Elliott Bay (18), North Harbor Island (16), Sinclair Inlet (13), West Waterway (8)	390
Dibenz(a,h)anthracene	Alki Beach (1), Brace Point (1), Duwamish River (14), Dyes Inlet (7), Eagle Harbor (18), East Waterway (3), Elliott Bay (74), Magnolia Bluff (9), North Harbor Island (9), Point Pulley (5), Port Madison (1), Port Townsend (5), Shilshole Bay (4), Sinclair Inlet (6), West Point (6), West Waterway (9)	12	Alki Beach (1), Brace Point (1), Duwamish River (7), Dyes Inlet (7), Eagle Harbor (11), Elliott Bay (44), Magnolia Bluff (7), North Harbor Island (7), Point Pulley (5), Port Madison (1), Port Townsend (5), Shilshole Bay (4), Sinclair Inlet (6), West Point (6), West Waterway (2)	33
Dibenzofuran	Alki beach (1), Brace Point (1), Central Sound (2), Duwamish River (11), Dyes Inlet (5), Eagle Harbor (7), East Waterway (1), Elliott Bay (42), Kellogg Island (2), Magnolia Bluff (3), North Harbor Island (15), Point Pulley (4), Port Townsend (1), Shilshole Bay (2), Sinclair Inlet (3), West Waterway (5)	15	Brace Point (1), Central Sound (2), Duwamish River (7), Dyes Inlet (5), Eagle Harbor (7), East Waterway (1), Elliott Bay (20), Magnolia Bluff (2), North Harbor Island (8), Point Pulley (4), Port Townsend (1), Shilshole Bay (1), Sinclair Inlet (3), West Waterway (2)	58
Diethyl phthalate	Dyes Inlet (3), Eagle Harbor (2), Elliott Bay (1), Magnolia Bluff (1), North Harbor Island (2), Port Madison (1), Port Townsend (1), Shilshole Bay (2), Sinclair Inlet (2), West Point (1), West Waterway (1)	61	Dyes Inlet (3), Eagle Harbor (1), Elliott Bay (1), Magnolia Bluff (1), North Harbor Island (2), Port Madison (1), Port Townsend (1), Shilshole Bay (2), Sinclair Inlet (2), West Waterway (1)	

Appendix A. Continued.

Chemical Contaminant	SQS Sample location (No. of samples)	SQS value	CSL Sample location (No. of samples)	CSL value
Dimethyl phthalate	Eagle Harbor (3), Elliott Bay (4), Kellogg Island (1), North Harbor Island (1)		Eagle Harbor (3), Elliott Bay (4), Kellogg Island (1), North Harbor Island (1)	53
Di-n-butyl phthalate	Duwamish River (2), Dyes Inlet (3), Elliott Bay (5), North Harbor Island (1), Point Pulley (1), Port Madison (1), Sinclair Inlet (3), West Point (6)	220	Duwamish River (2), Dyes Inlet (3), Point Pulley (1), Port Madison (1), Sinclair Inlet (3), West Point (1)	1700
Di-n-octyl phthalate	Duwamish River (1), Dyes Inlet (1), Elliott Bay (15), Shilshole Bay (1), Sinclair Inlet (1), West Point (20)	58	Elliott Bay (2), West Point (1)	4500
Fluoranthene	Alki Beach (1), Brace Point (3), Central Sound (6), Duwamish River (20), Dyes Inlet (8), Eagle Harbor (15), East Waterway (5), Elliott Bay (85), Jefferson Head (1), Liberty Bay (2), Magnolia Bluff (10), North Harbor Island (18), Point Pulley (7), Port Madison (4), Port Townsend (8), Richmond Beach (3), Seahurst Passage (2), Shilshole Bay (6), Sinclair Inlet (8), Useless Bay (1), Vashon Island (2), West Point (20), West Waterway (18)	160	Brace Point (3), Central Sound (5), Duwamish River (7), Dyes Inlet (7), Eagle Harbor (9), East Waterway (1), Elliott Bay (85), Jefferson Head (1), Liberty Bay (2), Magnolia Bluff (7), North Harbor Island (1), Point Pulley (7), Port Madison (4), Port Townsend (6), Richmond Beach (3), Seahurst Passage (2), Shilshole Bay (5), Sinclair Inlet (7), Useless Bay (1), Vashon Island (2), West Point (3), West Waterway (2)	1200
Fluorene	Alki Beach (1), Central Sound (3), Dogfish Bay (1), Duwamish River (12), Dyes Inlet (6), Eagle Harbor (14), East Waterway (3), Elliott Bay (65), Liberty Bay (1), Magnolia Bluff (6), North Harbor Island (13), Point Pulley (5), Port Townsend (2), Shilshole Bay (4), Sinclair Inlet (6), West Point (10), West Waterway (8)	23	Central Sound (2), Dogfish Bay (1), Duwamish River (8), Dyes Inlet (6), Eagle Harbor (11), East Waterway (1), Elliott Bay (26), Magnolia Bluff (4), North Harbor Island (5), Point Pulley (5), Port Townsend (2), Shilshole Bay (3), Sinclair Inlet (5), West Point (3), West Waterway (1)	79
Hexachlorobenzene	Duwamish River (3), Dyes Inlet (1), Elliott Bay (3), Magnolia Bluff (1), North Harbor Island (3), West Point (1), West Waterway (1)	0.38	Dyes Inlet (1), Elliott Bay (1), Magnolia Bluff (1), North Harbor Island (3), West Point (1), West Waterway (1)	2.3
Hexachlorobutadiene	Elliott Bay (3), North Harbor Island (2), West Point (2)	3.9	Elliott Bay (1), North Harbor Island (2), West Point (2)	6.2

Appendix A. Continued.

Chemical Contaminant	SQS Sample location (No. of samples)	SQS value	CSL Sample location (No. of samples)	CSL value
High Molecular Weight PAH	Alki Beach (2), Brace Point (3), Central Sound (6), Dogfish Bay (1), Duwamish River (17), Dyes Inlet (8), Eagle Harbor (15), East Waterway (11), Elliott Bay (88), Jefferson Head (1), Kellogg Island (4), Liberty Bay (2), Magnolia Bluff (10), North Harbor Island (21), Point Pulley (7), Port Madison (4), Port Townsend (6), Richmond Beach (3), Seahurst Passage (2), Shilshole Bay (6), Sinclair Inlet (8), Useless Bay (2), Vashon Island (3), West Point (21), West Waterway (24)	960	Alki Beach (1), Brace Point (3), Central Sound (5), Duwamish River (7), Dyes Inlet (7), Eagle Harbor (9), East Waterway (2), Elliott Bay (18), Jefferson Head (1), Liberty Bay (2), Magnolia Bluff (7), North Harbor Island (4), Point Pulley (7), Port Madison (4), Port Townsend (6), Richmond Beach (3), Seahurst Passage (2), Shilshole Bay (5), Sinclair Inlet (7), Useless Bay (2), Vashon Island (3), West Point (7), West Waterway (1)	
Indeno (1,2,3-cd) pyrene	Alki Beach (1), Brace Point (2), Central Sound (3), Duwamish River (18), Dyes Inlet (8), Eagle Harbor (17), East Waterway (3), Elliott Bay (88), Liberty Bay (1), Magnolia Bluff (10), North Harbor Island (15), Point Pulley (7), Port Madison (3), Port Townsend (3), Richmond Beach (1), Shilshole Bay (3), Sinclair Inlet (8), West Point (17), West Waterway (17)	34	Alki Beach (1), Brace Point (2), Central Sound (3), Duwamish River (9), Dyes Inlet (7), Eagle Harbor (8), Elliott Bay (42), Liberty Bay (1), Magnolia Bluff (7), North Harbor Island (8), North Shore (10), Point Pulley (7), Port Madison (3), Port Townsend (3), Richmond Beach (1), Shilshole Bay (3), Sinclair Inlet (8), West Point (13), West Waterway (3)	88
Lead	Duwamish River (11), Elliott Bay (25), Kellogg Island (1), North Harbor Island (4), Sinclair Inlet (5), West Waterway (9)	450	Duwamish River (9), Elliott Bay (16), Kellogg Island (1), North Harbor Island (3), Sinclair Inlet (3), West Waterway (8)	
Low Molecular Weight PAH	Alki Beach (1), Brace Point (3), Central Sound (5), Duwamish River (11), Dogfish Bay (1), Dyes Inlet (7), Eagle Harbor (13), East Waterway (3), Elliott Bay (54), Jefferson Head (1), Kellogg Island (1), Liberty Bay (2), Magnolia Bluff (9), North Harbor Island (13), Point Pulley (7), Port Madison (4), Port Townsend (6), Richmond Beach (3), Seahurst Passage (2), Shilshole Bay (6), Sinclair Inlet (7), Useless Bay (2), Vashon Island (3), West Point (5), West Waterway (5)	370	Brace Point (3), Central Sound (5), Duwamish River (8), Dogfish Bay (1), Dyes Inlet (7), Eagle Harbor (11), East Waterway (1), Elliott Bay (32), Jefferson Head (1), Liberty Bay (2), Magnolia Bluff (7), North Harbor Island (7), Point Pulley (7), Port Madison (4), Port Townsend (6), Richmond Beach (3), Seahurst Passage (2), Shilshole Bay (6), Sinclair Inlet (7), Useless Bay (2), Vashon Island (3), West Point (3), West Waterway (1)	780

Appendix A. Continued.

Chemical Contaminant	SQS Sample location (No. of samples)	SQS value	CSL Sample location (No. of samples)	CSL value
Mercury	Alki Beach (1), Central Sound (1), Duwamish River (42), Dyes Inlet (23), Eagle Harbor (1), East Passage (2), East Waterway (20), Elliott Bay (192), Four-Mile Rock (1), Kellogg Island (4), Magnolia Bluff (2), North Harbor Island (30), Sinclair Inlet (144), West Point (3), West Waterway (58), Williams Point (1)	0.41	Alki Beach (1), Duwamish River (29), Dyes Inlet (9), Eagle Harbor (1), East Waterway (10), Elliott Bay (139), Four-Mile Rock (1), Kellogg Island (1), North Harbor Island (25), Sinclair Inlet (133), West Point (1), West Waterway (40), Williams Point (1)	0.59
Naphthalene	Alki Beach (1), Bainbridge Island (1), Brace Point (1), Central Sound (3), Duwamish River (7), Dyes Inlet (7), Eagle Harbor (10), Elliott Bay (14), Magnolia Bluff (7), North Harbor Island (4), Point Pulley (7), Port Madison (2), Port Townsend (3), Shilshole Bay (2), Sinclair Inlet (6), West Point (2)	99	Brace Point (1), Central Sound (3), Duwamish River (7), Dyes Inlet (7), Eagle Harbor (10), Elliott Bay (9), Magnolia Bluff (7), North Harbor Island (3), Point Pulley (7), Port Madison (2), Port Townsend (3), Shilshole Bay (2), Sinclair Inlet (6), West Point (2)	170
N-Nitroso diphenylamine	Duwamish River (3), Elliott Bay (6), North Harbor Island (2), West Point (1), West Waterway (1)	11	Duwamish River (3), Elliott Bay (6), North Harbor Island (2), West Point (1), West Waterway (1)	11
Pentachlorophenol	East Waterway (1), Elliott Bay (6), North Harbor Island (3), West Waterway (1)	360	East Waterway (1), Elliott Bay (4), North Harbor Island (1)	690
Phenanthrene	Alki Beach (2), Brace Point (2), Central Sound (4), Dogfish Bay (1), Duwamish River (17), Dyes Inlet (7), Eagle Harbor (14), East Waterway (5), Elliott Bay (79), Jefferson Head (1), Liberty Bay (2), Magnolia Bluff (9), North Harbor Island (17), Point Pulley (7), Port Madison (9), Port Townsend (6), Richmond Beach (3), Seahurst Passage (1), Shilshole Bay (6), Sinclair Inlet (10), Useless Bay (1), Vashon Island (2), West Point (17), West Waterway (12), Williams Point (1)	100	Brace Point (2), Central Sound (4), Dogfish Bay (1), Duwamish River (8), Dyes Inlet (7), Eagle Harbor (10), Elliott Bay (28), Jefferson Head (1), Liberty Bay (2), Magnolia Bluff (7), North Harbor Island (6), Point Pulley (7), Port Madison (4), Port Townsend (6), Richmond Beach (3), Seahurst Passage (1), Shilshole Bay (6), Sinclair Inlet (7), Useless Bay (1), Vashon Island (2), West Point (3), West Waterway (1)	480

Appendix A. Continued.

Chemical Contaminant	SQS Sample location (No. of samples)	SQS value	CSL Sample location (No. of samples)	CSL value
Phenol	Dogfish Bay (2), Duwamish River (8), Eagle Harbor (5), East Waterway (2), Elliott Bay (15), Kellogg Island (10), Liberty Bay (3), North Beach (1), North Harbor Island (6), Sinclair Inlet (1), Keyport (1), West Point (3), West Waterway (15)	420	Dogfish Bay (2), Duwamish River (2), Elliott Bay (4), Kellogg Island (5), West Point (1), West Waterway (4)	1200
Pyrene	Brace Point (3), Central Sound (4), Duwamish River (7), Dyes Inlet (7), Eagle Harbor (9), Elliott Bay (24), Jefferson Head (1), Liberty Bay (2), Magnolia Bluff (7), North Harbor Island (2), Point Pulley (7), Port Madison (4), Port Townsend (6), Richmond Beach (3), Seahrust Passage (2), Shilshole Bay (6), Sinclair Inlet (7), Useless Bay (1), Vashon Island (3), West Point (6), West Waterway (1)	1000	Brace Point (3), Central Sound (5), Duwamish River (7), Dyes Inlet (7), Eagle Harbor (9), Elliott Bay (12), Jefferson Head (1), Liberty Bay (2), Magnolia Bluff (7), North Harbor Island (1), Point Pulley (7), Port Madison (4), Port Townsend (6), Richmond Beach (3), Seahrust Passage (2), Shilshole Bay (5), Sinclair Inlet (7), Useless Bay (1), Vashon Island (3), West Point (3)	1400
Silver	Duwamish River (7), Elliott Bay (18), West Point (5)		Duwamish River (7), Elliott Bay (18), West Point (5)	
Total benzofluoranthenes (b+k (+j))	Alki Beach (1), Brace Point (3), Central Sound (5), Dogfish Bay (1), Duwamish River (12), Dyes Inlet (8), Eagle Harbor (16), East Waterway (2), Elliott Bay (65), Jefferson Head (1), Liberty Bay (2), Magnolia Bluff (9), North Harbor Island (14), Point Pulley (7), Port Madison (4), Port Townsend (6), Richmond Beach (3), Seahurst Passage (2), Shilshole Bay (6), Sinclair Inlet (8), Useless Bay (1), Vashon Island (3), West Point (17), West Waterway (7)	230	Brace Point (3), Central Sound (5), Dogfish Bay (1), Duwamish River (9), Dyes Inlet (7), Eagle Harbor (13), Elliott Bay (65), Jefferson Head (1), Liberty Bay (2), Magnolia Bluff (7), North Harbor Island (9), Point Pulley (7), Port Madison (4), Port Townsend (6), Richmond Beach (3), Seahurst Passage (2), Shilshole Bay (6), Sinclair Inlet (7), Useless Bay (1), Vashon Island (3), West Point (8), West Waterway (1)	450
Total Polychlorinated Biphenyls	Duwamish River (127), Dyes Inlet (11), Eagle Harbor (5), East Waterway (23), Elliott Bay (108), Four-Mile Rock (2), Kellogg Island (10), Magnolia Bluff (4), North Harbor Island (22), Point Pulley (4), Port Madison (1), Port Townsend (1), Shilshole Bay (2), Sinclair Inlet (32), West Point (23), West Waterway (29)	12	Duwamish River (41), Dyes Inlet (6), Eagle Harbor (5), East Waterway (23), Elliott Bay (28), Four-Mile Rock (2), Kellogg Island (1), Magnolia Bluff (4), North Harbor Island (5), Point Pulley (4), Port Madison (1), Port Townsend (1), Shilshole Bay (2), Sinclair Inlet (7), West Point (6), West Waterway (2)	65

Appendix A. Continued.

Chemical Contaminant	SQS Sample location (No. of samples)	SQS value	CSL Sample location (No. of samples)	CSL value
Zinc	Duwamish River (13), Dyes inlet (2), East Waterway (3), Elliott Bay (47), Four -Mile Rock (1), Kellogg Island (5), North Harbor Island (19), Sinclair Inlet (36), West Waterway (11)	410	Duwamish River (1), Elliott Bay (11), Kellogg Island (1), North Harbor Island (4), Sinclair Inlet (7), West Waterway (4)	960

Appendix B

Navigation report for the 1998 central Puget Sound sampling stations.

Appendix B. Navigation report for the 1998 central Puget Sound sampling stations.

Stratum	Sample	Station	Deploy-ment No.	Date	GPS Time	GPS PDOP/HDOP	Stern Transd. Depth m.	Predicted Tide (m.): Nearest Station	Predicted Mudline Depth, m. (MLLW)	Distance to Station (m)	LORAN-C Yankee	LORAN-C Zulu (shaded =Best no.)	DGPS (Trimble NT300D) NAD 1983 Decimal Minutes Latitude	DGPS Longitude	Station Target NAD 1983 Decimal Minutes Latitude	Station Target Longitude	Van Veen Grab Type
01	106	1	1	30-Jun-98	0911	0.9/1.2	13.3	1.5	11.8	1.0	28311.3	42273.8	48 02.8153	122 45.8271	48 02.8158	122 45.8275	heavy
South Port Townsend			2		0925	0.9/1.2	13.3	1.5	11.8	0.3	28311.3	42273.8	48 02.8159	122 45.8274			
			3		0935	0.9/1.2	13.3	1.5	11.8	1.3	28311.3	42273.8	48 02.8151	122 45.8276			
01	107	2	1	30-Jun-98	1011	1.8/1.0	20.9	1.5	19.4	2.1	28303.5	42276.8	48 02.4102	122 44.6112	48 02.4110	122 44.6098	heavy
South Port Townsend			2		1025	1.8/1.0	20.9	1.4	19.5	1.9	28303.4	42276.8	48 02.4118	122 44.6108			
			3		1033	1.7/0.9	20.8	1.4	19.4	0.7	28303.5	42276.8	48 02.4108	122 44.6093			
01	108	3	1	30-Jun-98	1829	1.9/1.1	26.0	1.3	24.7	1.0	28323.8	42276.2	48 04.1881	122 45.9197	48 04.1880	122 45.9190	light
South Port Townsend			2		1840	1.8/1.0	26.0	1.4	24.6	1.0	28323.8	42276.2	48 04.1879	122 45.9182			
			3		1849	1.8/1.0	26.0	1.4	24.6	3.0	28323.8	42276.2	48 04.1890	122 45.9209			
02	109	1.2	1	29-Jun-98	1525	4.0/2.3	33.8	0.3	33.5	1.5	28337.9	42288.4	48 06.6493	122 43.7254	48 06.6500	122 43.7263	heavy
Port Townsend			2		1538	1.8/1.0	34.0	0.3	33.7	1.3	28337.9	42288.4	48 06.6498	122 43.7252			
			3		1548	1.9/1.0	34.2	0.4	33.8	1.5	28337.9	42288.4	48 06.6504	122 43.7273			
			4		1600	2.0/1.1	34.4	0.4	34.0	1.4	28338.0	42288.4	48 06.6500	122 43.7253			
			5		1608	2.0/1.1	34.4	0.5	33.9	2.0	28337.9	42288.3	48 06.6497	122 43.7278			
02	110	2.2	1	29-Jun-98	1339	2.3/1.1	13.2	0.2	13.0	1.7	28339.1	42289.9	48 06.9001	122 43.4414	48 06.9000	122 43.4421	heavy
Port Townsend			2		1426	2.3/1.1	12.8	0.2	12.6	3.3	28339.2	42289.9	48 06.9006	122 43.4396			
			3		1437	2.3/1.1	13.2	0.2	13.0	1.2	28339.2	42289.9	48 06.8994	122 43.4417			
			4		1446	2.2/1.1	12.9	0.2	12.7	0.9	28339.2	42289.8	48 06.9005	122 43.4418			
02	111	3	1	29-Jun-98	1234	1.7/0.9	15.3	0.5	14.8	0.8	28338.2	42283.2	48 06.1756	122 45.0007	48 06.1757	122 45.0001	heavy
Port Townsend			2		1245	1.7/0.9	15.3	0.4	14.9	1.8	28338.2	42283.2	48 06.1759	122 44.9986			
			3		1254	1.7/0.9	15.2	0.4	14.8	2.4	28338.2	42283.2	48 06.1770	122 45.0006			
04	112	2.4	1	30-Jun-98	1533	1.8/1.0	26.0	0.7	25.3	1.2	28220.8	42316.5	47 58.8913	122 30.2027	47 58.8918	122 30.2032	heavy
South Admiralty Inlet			2		1548	1.8/1.0	25.0	0.6	24.4	1.5	28220.8	42316.6	47 58.8923	122 30.2023			
			3		1557	1.9/1.0	26.0	0.6	25.4	0.4	28220.8	42316.6	47 58.8915	122 30.2028			
04	116	3.2	1	30-Jun-98	1440	2.2/1.1	61.0	0.8	60.2	3.5	28212.1	42313.2	47 57.8045	122 30.4770	47 57.8047	122 30.4741	heavy
South Admiralty Inlet			2		1453	2.1/1.2	62.0	0.8	61.2	4.9	28212.1	42313.3	47 57.8035	122 30.4776			
			3		1509	2.1/1.3	67.0	0.7	66.3	7.7	28212.1	42313.4	47 57.8055	122 30.4679			
04	117	4	1	30-Jun-98	1142	1.6/0.9	45.0	1.4	43.6	1.7	28265.1	42284.2	47 59.6249	122 40.6872	47 59.6239	122 40.6870	heavy
South Admiralty Inlet			2		1200	1.6/1.1	46.0	1.3	44.7	2.2	28265.0	42284.2	47 59.6238	122 40.6853			
			3		1212	1.9/1.1	46.0	1.3	44.7	0.9	28265.0	42284.2	47 59.6241	122 40.6864			
			4		1230	1.8/1.0	45.0	1.2	43.8	1.4	28265.0	42284.2	47 59.6233	122 40.6878			

Appendix B. Continued.

Stratum	Sample	Station	Deploy-ment No.	Date	GPS Time	GPS PDOP/ HDOP	Stern Transd. Depth m.	Predicted Tide (m.): Nearest Station	Predicted Mudline Depth, m. (MLLW)	Distance to Station (m)	LORAN-C Yankee	LORAN-C Zulu (shaded =Best no.)	DGPS (Trimble NT300D) NAD 1983 Decimal Minutes Latitude	DGPS Longitude	Station Target NAD 1983 Decimal Minutes Latitude	Station Target Longitude	Van Veen Grab Type
05	118	1	1	26-Jun-98	1008	1.5/0.9	191.0	1.0	190.0	4.6	28101.0	42309.8	47 54.4087	122 20.2104	47 54.4102	122 20.2072	heavy
Possession Sound			2		1034	1.8/1.0	191.0	0.6	190.4	6.4	28144.1	42338.6	47 54.4112	122 20.2122			
			3		1052	1.7/0.9	190.0	0.4	189.6	7.0	28144.1	42338.7	47 54.4090	122 20.2126			
			4		1114	2.3/1.1	189.0	0.1	188.9	4.0	28144.1	42338.7	47 54.4117	122 20.2053			
05	119	2	1	26-Jun-98	1305	1.7/0.9	213.0	-0.6	213.6	3.7	28101.0	42309.8	47 52.5708	122 28.9305	47 52.5688	122 28.9302	heavy
Possession Sound			2		1328	2.1/1.1	211.0	-0.6	211.6	2.9	28161.1	42307.7	47 52.5674	122 28.9311			
			3		1349	2.5/1.3	211.0	-0.5	211.5	3.9	28161.1	42307.6	47 52.5681	122 28.9334			
			4		1408	2.2/1.1	211.0	-0.4	211.4	3.2	28161.0	42307.6	47 52.5675	122 28.9319			
			5		1430	2.4/1.1	211.0	-0.2	211.2	6.4	28161.1	42307.7	47 52.5662	122 28.9340			
05	120	3	1	26-Jun-98	1514	2.0/1.2	201.0	0.3	200.7	7.1	28159.9	42306.8	47 52.3663	122 29.0968	47 52.3691	122 29.0927	heavy
Possession Sound			2		1532	3.9/2.3	201.0	0.5	200.5	9.0	28101.0	42309.8	47 52.3653	122 29.0976			
			3		1600	1.9/1.0	201.0	0.8	200.2	7.2	28160.0	42306.7	47 52.3676	122 29.0982			
			4		1615	1.9/1.0	202.0	1.1	200.9	7.9	28160.0	42306.8	47 52.3696	122 29.0864			
			5		1630	1.9/1.1	202.0	1.3	200.7	9.9	28159.9	42306.8	47 52.3632	122 29.0922			
06	121	1	1	25-Jun-98	1251	1.7/0.9	9.4	-0.7	10.1	2.1	28098.0	42312.8	47 47.3988	122 23.8904	47 47.3995	122 23.8916	heavy
Central Basin			2		1305	1.7/0.9	9.2	-0.7	9.9	2.4	28098.0	42312.9	47 47.3998	122 23.8897			
			3		1314	1.7/0.9	9.8	-0.6	10.4	0.0	28098.1	42312.9	47 47.3995	122 23.8916			
			4		1324	2.0/1.0	9.8	-0.6	10.4	0.5	28098.1	42312.9	47 47.3998	122 23.8915			
06	122	2	1	25-Jun-98	1416	2.2/1.1	200.0	-0.1	200.1	3.1	28067.8	42296.4	47 42.5849	122 26.3592	47 42.5851	122 26.3568	heavy
Central Basin			2		1441	2.3/1.1	200.0	0.2	199.8	4.2	28067.8	42296.4	47 42.5832	122 26.3588			
			3		1459	2.2/1.1	201.0	0.5	200.5	3.0	28067.8	42296.4	47 42.5842	122 26.3547			
06	123	3	1	25-Jun-98	1553	1.8/1.0	218.0	1.3	216.7	2.6	28101.0	42309.8	47 47.3109	122 24.8648	47 47.3107	122 24.8669	heavy
Central Basin			2		1615	1.9/1.0	220.0	1.7	218.3	2.8	28101.0	42309.8	47 47.3112	122 24.8648			
			3		1643	2.0/1.1	221.0	2.0	219.0	2.0	28101.0	42309.8	47 47.3097	122 24.8671			
07	124	1	1	12-Jun-98	1301	2.6/1.6	27.9	-0.5	28.4	0.4	28090.1	42280.5	47 42.8288	122 31.6393	47 42.8291	122 31.6394	heavy
Port Madison			2		1312	1.6/0.9	28.5	-0.5	29.0	1.4	28090.1	42280.7	47 42.8297	122 31.6400			
			3		1324	2.0/1.1	28.4	-0.5	28.9	1.8	28090.1	42280.6	47 42.8289	122 31.6409			
07	125	2	1	12-Jun-98	1127	1.8/1.0	39.0	0.0	39.0	1.2	28101.5	42280.8	47 43.9833	122 32.2353	47 43.9828	122 32.2354	heavy
Port Madison			2		1142	1.7/1.0	38.9	-0.2	39.1	2.4	28101.5	42280.9	47 43.9814	122 32.2352			
			3		1152	1.5/0.9	38.8	-0.2	39.0	2.5	28101.5	42280.8	47 43.9818	122 32.2352			

Appendix B. Continued.

Stratum	Sample	Station	Deploy-ment No.	Date	GPS Time	GPS PDOP/ HDOP	Stern Transd. Depth m.	Predicted Tide (m.): Nearest Station	Predicted Mudline Depth, m. (MLLW)	Distance to Station (m)	LORAN-C Yankee	LORAN-C Zulu (shaded =Best no.)	DGPS (Trimble NT300D) NAD 1983 Decimal Minutes Latitude	DGPS Longitude	Station Target NAD 1983 Decimal Minutes Latitude	Station Target Longitude	Van Veen Grab Type
Location																	
07	126	3	1	12-Jun-98	1036	1.5/0.9	45.4	0.5	44.9	2.2	28096.6	42281.3	47 43.5620	122 31.8303	47 43.5613	122 31.8290	heavy
Port Madison			2		1051	1.5/0.9	45.4	0.4	45.0	3.2	28096.5	42281.3	47 43.5624	122 31.8270			
			3		1101	1.5/0.9	45.3	0.3	45.0	2.3	28096.5	42281.3	47 43.5605	122 31.8276			
08	127	1	1	11-Jun-98	1258	2.5/1.5	227.0	-5.0	232.0	1.8	28063.0	42288.9	47 41.2105	122 27.9820	47 41.2097	122 27.9824	light
West Point			2		1320	1.6/0.9	227.0	-0.4	227.4	5.0	28063.0	42288.9	47 41.2092	122 27.9784			
			3		1336	1.9/1.1	227.0	-0.3	227.3	2.6	28063.0	42288.9	47 41.2109	122 27.9814			
08	128	2	1	11-Jun-98	1401	1.7/0.9	168.0	0.0	168.0	1.0	28055.7	42292.7	47 40.9650	122 26.6008	47 40.9656	122 26.6009	light
West Point			2		1422	2.0/1.0	168.0	0.2	167.8	1.3	28055.8	42292.6	47 40.9649	122 26.6010			
			3		1439	2.4/1.2	168.0	0.4	167.6	2.0	28055.7	42292.7	47 40.9644	122 26.6005			
08	129	3	1	12-Jun-98	1411	1.7/0.9	239.0	-0.3	239.3	3.7	28054.4	42289.3	47 40.4082	122 27.3889	47 40.4110	122 27.3865	light
West Point			2		1431	2.2/1.1	239.0	-0.1	239.1	4.2	28054.4	42289.3	47 40.4084	122 27.3895			
			3		1448	1.8/1.1	239.0	0.0	239.0	6.1	28054.3	42289.3	47 40.4082	122 27.3894			
08	113	4	1	1-Jul-98	1244	1.7/0.9	217.0	2.0	215.0	2.7	28064.9	42286.8	47 41.1219	122 28.6614	47 41.1209	122 28.6597	light
West Point			2		1303	2.0/1.0	217.0	2.0	215.0	3.0	28064.8	42286.6	47 41.1194	122 28.6589			
			3		1317	2.2/1.1	217.0	1.9	215.1	2.7	28064.9	42286.7	47 41.1221	122 28.6610			
09	130	1	1	11-Jun-98	0937	2.6/1.3	14.4	0.9	13.5	0.6	28040.5	42275.4	47 37.3660	122 30.0950	47 37.3658	122 30.0955	light
Eagle Harbor			2		0950	2.4/1.3	14.9	0.8	14.1	2.4	28040.4	42275.4	47 37.3652	122 30.0938			
			3		1000	2.2/1.2	14.9	0.6	14.3	5.3	28040.5	42275.4	47 37.3647	122 30.0914			
09	131	2	1	11-Jun-98	1024	2.1/1.3	11.0	0.3	10.7	1.4	28040.5	42273.2	47 37.0882	122 30.6499	47 37.0885	122 30.6509	light
Eagle Harbor			2		1034	1.5/0.9	10.8	0.2	10.6	1.9	28040.5	42273.2	47 37.0886	122 30.6493			
			3		1043	1.5/0.9	10.7	0.1	10.6	1.8	28040.6	42273.3	47 37.0895	122 30.6510			
09	132	3.2	1	11-Jun-98	1112	1.8/1.0	12.2	-0.2	12.4	1.0	28041.0	42274.2	47 37.2555	122 30.4339	47 37.2550	122 30.4342	heavy
Eagle Harbor			2		1123	1.8/1.0	12.1	-0.3	12.4	0.7	28040.9	42274.1	47 37.2547	122 30.4345			
			3		1135	1.8/1.0	12.0	-0.4	12.4	0.2	28040.5	42273.2	47 37.2550	122 30.4341			
			4		1142	1.8/1.0	11.9	-0.4	12.3	1.0	28041.0	42274.2	47 37.2552	122 30.4335			
10	133	1	1	5-Jun-98	1037	2.0/1.2	27.1	0.8	26.3	0.5	28011.8	42261.1	47 32.6617	122 32.0799	47 32.6619	122 32.0801	heavy
Central Basin			2		1047	2.1/1.3	27.1	0.9	26.2	1.0	28011.9	42261.1	47 32.6622	122 32.0795			
			3		1056	1.5/0.9	27.6	0.9	26.7	1.7	28011.8	42261.0	47 32.6616	122 32.0788			
10	134	2.2	1	5-Jun-98	1328	2.5/1.6	46.2	2.2	44.0	2.5	28003.4	42262.0	47 31.9061	122 31.3737	47 31.9075	122 31.3740	heavy
Central Basin			2		1340	2.0/1.2	47.0	2.3	44.7	0.7	28003.4	42262.0	47 31.9079	122 31.3741			
			3		1349	2.0/1.2	48.0	2.3	45.7	1.5	28003.4	42262.0	47 31.9070	122 31.3729			
10	135	3	1	5-Jun-98	1125	2.0/1.2	38.6	1.2	37.4	0.4	28090.5	42265.5	47 31.0757	122 29.7035	47 31.0757	122 29.7031	heavy
Central Basin			2		1136	1.8/1.0	38.7	1.3	37.4	1.5	28090.5	42265.5	47 31.0754	122 29.7020			
			3		1145	1.8/1.0	39.0	1.3	37.7	1.2	28090.5	42265.5	47 31.0751	122 29.7029			
11	136	1	1	17-Jun-98	1230	1.6/1.0	250.0	2.2	247.8	0.9	28036.6	42282.2	47 37.8017	122 28.1570	47 37.8014	122 28.1573	heavy
Central Basin			2		1249	2.0/1.2	250.0	2.1	247.9	3.5	28036.6	42282.2	47 37.8020	122 28.1544			

Appendix B. Continued.

Stratum	Sample	Station	Deploy-ment No.	Date	GPS Time	GPS PDOP/ HDOP	Stern Transd. Depth m.	Predicted Tide (m.): Nearest Station	Predicted Mudline Depth, m. (MLLW)	Distance to Station (m)	LORAN-C Yankee	LORAN-C Zulu (=Best no.)	DGPS (Trimble NT300D) NAD 1983 Decimal Minutes Latitude	DGPS Longitude	Station Target NAD 1983 Decimal Minutes Latitude	Station Target Longitude	Van Veen Grab Type
			3		1306	1.9/1.1	248.0	2.0	246.0	0.2	28036.6	42282.2	47 37.8014	122 28.1574			
11	137	2	1	17-Jun-98	1343	1.7/0.9	213.0	1.8	211.2	1.7	28026.0	42282.0	47 36.7397	122 27.5746	47 36.7397	122 27.5759	heavy
Central Basin			2		1401	2.1/1.1	213.0	1.7	211.3	1.8	28026.1	42282.1	47 36.7406	122 27.5753			
			3		1417	2.4/1.2	213.0	1.6	211.4	0.4	28026.0	42282.0	47 36.7396	122 27.5762			
11	138	3.2	1	17-Jun-98	1027	1.5/0.9	214.0	2.4	211.6	2.3	27977.1	42275.8	47 31.0872	122 26.2506	47 31.0857	122 26.2519	heavy
Central Basin			2		1047	1.8/1.0	213.0	2.4	210.6	2.0	27977.1	42275.9	47 31.0849	122 26.2531			
			3		1101	1.8/1.0	213.0	2.4	210.6	1.6	27977.1	42275.8	47 31.0863	122 26.2510			
12	139	1	1	1-Jun-98	1103	2.1/1.3	236.0	2.3	233.7	3.3	27941.2	42276.4	47 27.5742	122 23.9584	47 27.5747	122 23.9609	light
East Passage			2		1130	1.5/0.9	235.0	2.3	232.7	1.6	27941.2	42276.4	47 27.5745	122 23.9603			
			3		1134	1.5/0.9	234.0	2.2	231.8	2.7	27941.2	42276.4	47 27.5742	122 23.9588			
12	140	2	1	1-Jun-98	1310	2.2/1.1	191.0	1.8	189.2	7.1	27921.8	42276.7	47 25.6808	122 22.6849	47 25.6790	122 22.6900	light
East Passage			2		1334	1.9/1.1	190.0	1.6	188.4	0.2	27921.9	42276.7	47 25.6789	122 22.6900			
			3		1350	1.6/0.9	190.0	1.5	188.5	2.4	27921.8	42276.7	47 25.6778	122 22.6904			
12	141	3.2	1	1-Jun-98	1540	1.8/1.1	97.0	0.7	96.3	2.3	27900.1	42280.5	47 24.0727	122 20.3352	47 24.0734	122 20.3366	heavy
East Passage			2		1553	2.2/1.1	97.0	0.7	96.3	0.4	27900.2	42280.6	47 24.0733	122 20.3363			
			3		1608	2.2/1.1	97.0	0.6	96.4	0.6	27900.1	42280.5	47 24.0731	122 20.3366			
			4		1617	2.2/1.1	96.0	0.6	95.4	1.9	27900.1	42280.6	47 24.0734	122 20.3352			
13	142	1	1	10-Jun-98	1314	1.6/0.9	4.4	-0.2	4.6	0.5	28122.3	42259.3	47 43.3897	122 38.8212	47 43.3896	122 38.8216	light
Liberty Bay			2		1327	2.0/1.0	4.5	0.0	4.5	1.0	28122.3	42259.3	47 43.3898	122 38.8223			
			3		1334	1.9/1.6	4.5	0.0	4.5	1.9	28122.3	42259.3	47 43.3904	122 38.8229			
			4		1341	2.1/1.1	4.6	0.1	4.5	0.7	28122.3	42259.3	47 43.3902	122 38.8216			
13	143	2	1	10-Jun-98	1403	1.7/0.9	4.2	0.4	3.8	0.9	28121.4	42258.7	47 43.2209	122 38.9393	47 43.2205	122 38.9398	light
Liberty Bay			2		1415	1.7/0.9	4.4	0.5	3.9	0.5	28121.4	42258.7	47 43.2202	122 38.9396			
			3		1424	1.7/0.9	4.4	0.6	3.8	1.8	28121.4	42258.7	47 43.2210	122 38.9411			
			4		1431	2.1/1.1	4.5	0.7	3.8	1.9	28121.4	42258.7	47 43.2207	122 38.9413			
13	144	3	1	10-Jun-98	1501	1.8/1.1	11.0	1.1	9.9	1.3	28120.6	42260.0	47 43.3097	122 38.5268	47 43.3091	122 38.5263	light
Liberty Bay			2		1519	2.2/1.1	11.2	1.4	9.8	1.7	28120.6	42260.0	47 43.3091	122 38.5277			
			3		1530	2.3/1.1	11.4	1.6	9.8	1.3	28120.6	42260.1	47 43.3096	122 38.5255			
			4		1538	2.4/1.1	11.5	1.7	9.8	1.8	28120.6	42260.0	47 43.3095	122 38.5276			

Appendix B.   Continued.

Stratum	Sample	Station	Deploy-ment No.	Date	GPS Time	GPS PDOP/ HDOP	Stern Transd. Depth m.	Predicted Tide (m.): Nearest Station	Predicted Mudline Depth, m. (MLLW)	Distance to Station (m)	LORAN-C Yankee	LORAN-C Zulu (=Best no.)	DGPS (Trimble NT300D) NAD 1983 Decimal Minutes Latitude	DGPS Longitude	Station Target NAD 1983 Decimal Minutes Latitude	Station Target Longitude	Van Veen Grab Type
Location																	
14	145	1	1	10-Jun-98	1036	1.6/1.0	3.7	0.0	3.7	2.4	28114.1	42261.6	47 42.8806	122 37.7592	47 42.8818	122 37.7584	heavy
Keyport			2		1046	1.6/1.0	3.5	-0.1	3.6	2.0	28114.1	42261.6	47 42.8816	122 37.7568			
			3		1053	1.6/1.0	3.5	-0.2	3.7	0.6	28114.1	42261.6	47 42.8816	122 37.7588			
			4		1102	3.0/1.9	3.3	-0.3	3.6	1.5	28114.1	42261.6	47 42.8815	122 37.7572			
			5		1109	1.1/1.3	3.3	-0.3	3.6	1.6	28114.1	42261.7	47 42.8813	122 37.7597			
14	146	2	1	10-Jun-98	1145	2.1/1.2	6.7	-0.5	7.2	1.9	28119.2	42259.9	47 43.1631	122 38.4778	47 43.1640	122 38.4771	light
Keyport			2		1155	2.1/1.2	6.8	-0.5	7.3	2.2	28119.2	42260.0	47 43.1651	122 38.4762			
			3		1203	2.1/1.1	6.8	-0.5	7.3	0.8	28119.2	42259.9	47 43.1640	122 38.4777			
			4		1210	1.3/1.9	6.8	-0.5	7.3	1.2	28119.2	42260.0	47 43.1640	122 38.4762			
14	147	3	1	10-Jun-98	0946	3.2/1.5	5.3	0.5	4.8	1.6	28111.6	42259.6	47 42.3907	122 38.1330	47 42.3899	122 38.1325	heavy
Keyport			2		0956	2.9/1.4	5.3	0.4	4.9	2.3	28111.6	42259.6	47 42.3898	122 38.1305			
			3		1004	2.6/1.3	4.8	0.3	4.5	0.6	28111.6	42259.6	47 42.3899	122 38.1320			
			4		1010	2.4/1.3	4.8	0.2	4.6	1.5	28111.6	42259.6	47 42.3907	122 38.1328			
			5		1017	2.2/1.3	4.4	0.1	4.3	1.1	28111.6	42259.7	47 42.3894	122 38.1330			
15	148	1	1	9-Jun-98	1645	4.0/2.3	13.5	2.9	10.6	2.0	28099.0	42262.7	47 41.5765	122 36.6076	47 41.5757	122 36.6066	light
NW Bainbridge Island			2		1656	1.8/1.0	13.7	3.1	10.6	1.7	28099.1	42262.6	47 41.5748	122 36.6063			
			3		1705	1.8/1.0	13.7	3.1	10.6	2.4	28099.1	42262.6	47 41.5750	122 36.6049			
15	149	2	1	9-Jun-98	1437	2.1/1.1	5.5	1.3	4.2	1.9	28092.1	42266.3	47 41.3264	122 35.3354	47 41.3257	122 35.3366	heavy
NW Bainbridge Island			2		1457	2.5/1.3	5.8	1.6	4.2	1.4	28092.1	42266.2	47 41.3263	122 35.3374			
			3		1505	1.8/1.1	5.8	1.7	4.1	2.5	28092.2	42266.2	47 41.3265	122 35.3347			
			4		1513	2.1/1.1	6.1	1.8	4.3	4.3	28092.1	42266.3	47 41.3266	122 35.3333			
			5		1524	2.2/1.1	6.2	2.0	4.2	0.6	28092.2	42266.3	47 41.3258	122 35.3371			
			6		1532	2.3/1.1	6.3	2.1	4.2	2.1	28092.1	42266.2	47 41.3246	122 35.3367			
			7		1537	2.3/1.1	6.3	2.2	4.1	0.6	28092.2	42266.2	47 41.3255	122 35.3363			
			8		1545	2.3/1.1	6.5	2.3	4.2	1.9	28092.1	42266.2	47 41.3247	122 35.3367			
15	150	3	1	9-Jun-98	1335	1.9/1.1	16.5	0.5	16.0	0.3	28087.9	42266.1	47 40.8740	122 35.1297	47 40.8742	122 35.1298	light
NW Bainbridge Island			2		1352	1.8/1.0	16.6	0.7	15.9	2.3	28087.8	42266.0	47 40.8729	122 35.1297			
			3		1404	1.7/0.9	16.6	0.9	15.7	1.8	28087.8	42266.1	47 40.8751	122 35.1291			
16	151	1	1	9-Jun-98	1235	2.2/1.1	17.6	-0.1	17.7	1.0	28077.1	42259.5	47 38.9657	122 36.2096	47 38.9657	122 36.2088	light
SW Bainbridge Island			2		1244	2.2/1.1	17.7	-0.1	17.8	0.3	28077.1	42259.5	47 38.9656	122 36.2086			
			3		1254	2.0/1.1	18.0	0.1	17.9	1.3	28077.1	42259.5	47 38.9653	122 36.2079			
			4		1303	2.8/1.5	18.0	0.1	17.9	1.4	28077.1	42259.5	47 38.9665	122 36.2087			
16	152	2	1	8-Jun-98	1412	1.7/0.9	24.8	1.5	23.3	0.8	28051.6	42257.3	47 36.1423	122 35.3440	47 36.1426	122 35.3437	light
SW Bainbridge Island			2		1425	1.7/0.9	24.8	1.6	23.2	1.2	28051.6	42257.2	47 36.1426	122 35.3428			

Appendix B. Continued.

Stratum	Sample	Station	Deployment No.	Date	GPS Time	GPS PDOP/HDOP	Stern Transd. Depth m.	Predicted Tide (m.): Nearest Station	Predicted Mudline Depth, m. (MLLW)	Distance to Station (m)	LORAN-C Yankee	LORAN-C Zulu (shaded =Best no.)	DGPS (Trimble NT300D) NAD 1983 Decimal Minutes Latitude	DGPS Longitude	Station Target NAD 1983 Decimal Minutes Latitude	Station Target Longitude	Van Veen Grab Type
Location																	
			3		1440	2.1/1.1	24.9	1.8	23.1	3.2	28051.6	42257.3	47 36.1435	122 35.3414			
			4		1450	2.2/1.1	25.0	2.0	23.0	0.1	28051.6	42257.3	47 36.1426	122 35.3436			
16	153	3	1	8-Jun-98	1218	1.7/1.0	34.5	0.2	34.3	5.1	28061.0	42260.9	47 37.5503	122 34.8743	47 37.5487	122 34.8779	light
SW Bainbridge Island			2		1233	2.3/1.1	34.6	0.3	34.3	2.6	28061.0	42260.9	47 37.5496	122 34.8795			
			3		1256	2.0/1.1	34.6	0.5	34.1	2.0	28061.0	42260.9	47 37.5487	122 34.8796			
			4		1304	2.8/1.5	34.6	0.6	34.0	1.1	28060.9	42260.9	47 37.5485	122 34.8771			
17	154	1.8	1	9-Jun-98	1031	2.1/1.3	4.6	-0.2	4.8	0.0	28035.1	42265.4	47 35.6053	122 32.2417	47 35.6053	122 32.2417	heavy
Rich Passage			2		1054	1.5/1.2	4.7	-0.3	5.0	1..2	28035.1	42265.4	47 35.6047	122 32.2413			
			3		1105	2.1/1.2	4.6	-0.3	4.9	2.5	28035.1	42265.5	47 35.6053	122 32.2437	Moved station to slightly deeper water		
			4		1111	1.5/0.9	4.7	-0.3	5.0	2.4	28035.1	42265.4	47 35.6061	122 32.2400			
			5		1118	1.5/0.9	4.7	-0.3	5.0	1.7	28035.2	42265.4	47 35.6061	122 32.2408			
17	155	2.2	1	8-Jun-98	1109	2.1/1.2	5.0	-0.1	5.1	3.9	28042.2	42263.3	47 36.0357	122 33.2248	47 36.0346	122 33.2276	heavy
Rich Passage			2		1124	1.8/1.0	4.7	-0.1	4.8	4.0	28042.2	42263.3	47 36.0370	122 33.2290			
			3		1135	1.8/1.0	5.0	-0.1	5.1	1.9	28042.2	42263.3	47 36.0354	122 33.2285			
			4		1142	1.8/1.0	5.1	0.0	5.1	3.3	28061.0	42260.9	47 36.0362	122 33.2288			
17	156	3	1	8-Jun-98	1528	2.3/1.1	46.2	2.4	43.8	3.3	28039.7	42255.8	47 34.7533	122 35.0472	47 34.7518	122 35.0457	heavy
Rich Passage			2		1544	2.4/1.1	46.2	2.6	43.6	2.3	28039.7	42255.7	47 34.7515	122 35.0476			
			3		1559	2.3/1.1	47.0	2.7	44.3	0.5	28039.7	42255.7	47 34.7521	122 35.0459			
			4		1609	2.2/1.1	47.0	2.8	44.2	2.2	28039.7	42255.7	47 34.7508	122 35.0466			
			5		1621	2.1/1.2	47.3	2.9	44.4	1.6	28039.7	42255.8	47 34.7522	122 35.0445			
			6		1635	2.5/1.8	47.1	3.0	44.1	1.8	28039.7	42255.7	47 34.7510	122 35.0447			
18	157	1	1	4-Jun-98	1356	2.0/1.1	22.9	2.4	20.5	1.5	28039.2	42251.3	47 34.1432	122 36.1410	47 34.1436	122 36.1399	heavy
Port Orchard			2		1414	0.9/1.4	22.8	2.5	20.3	2.2	28039.2	42251.3	47 34.1443	122 36.1384			
			3		1426	0.9/1.4	22.8	2.5	20.3	0.9	28039.1	42251.2	47 34.1435	122 36.1392			
			4		1437	1.7/0.9	22.7	2.5	20.2	1.1	28039.2	42251.3	47 34.1438	122 36.1407			
18	158	2.3	1	4-Jun-98	1543	2.2/1.1	12.9	2.5	10.4	0.5	28036.1	42254.1	47 34.1703	122 35.2386	47 34.1701	122 35.2389	heavy
Port Orchard			2		1554	2.3/1.1	12.4	2.4	10.0	1.9	28036.1	42254.0	47 34.1691	122 35.2384			
			3		1604	2.3/1.1	12.5	2.4	10.1	2.5	28036.1	42254.0	47 34.1695	122 35.2371			
			4		1616	2.3/1.1	12.2	2.3	9.9	1.6	28036.1	42254.1	47 34.1694	122 35.2382			

Appendix B. Continued.

Stratum	Sample	Station	Deployment No.	Date	GPS Time	GPS PDOP/ HDOP	Stern Transd. Depth m.	Predicted Tide (m.): Nearest Station	Predicted Mudline Depth, m. (MLLW)	Distance to Station (m)	LORAN-C Yankee	LORAN-C Zulu (shaded =Best no.)	DGPS (Trimble NT300D) NAD 1983 Decimal Minutes Latitude	DGPS (Trimble NT300D) NAD 1983 Decimal Minutes Longitude	Station Target NAD 1983 Decimal Minutes Latitude	Station Target NAD 1983 Decimal Minutes Longitude	Van Veen Grab Type
Location																	
18	159	3.3	1	5-Jun-98	1449	2.1/1.1	8.0	2.6	5.4	1.6	28039.9	42249.3	47 33.9718	122 36.6535	47 33.9717	122 36.6548	heavy
Port Orchard			2		1501	2.2/1.1	7.8	2.6	5.2	3.1	28039.9	42249.3	47 33.9715	122 36.6574			
			3		1513	2.2/1.1	7.9	2.7	5.2	0.1	28039.9	42249.3	47 33.9720	122 36.6547			
			4		1522	1.1/1.4	8.2	2.7	5.5	4.5	28039.9	42249.3	47 33.9693	122 36.6542			
19	160	1	1	4-Jun-98	1001	2.6/1.3	7.6	1.0	6.6	0.7	28041.0	42234.6	47 32.0540	122 40.6130	47 32.0543	122 40.6131	light
Sinclair Inlet			2		1012	2.5/1.3	7.7	1.1	6.6	1.7	28041.0	42234.6	47 32.0542	122 40.6145			
			3		1020	2.4/1.3	7.7	1.1	6.6	0.7	28041.1	42234.6	47 32.0546	122 40.6128			
19	161	2	1	4-Jun-98	1049	2.1/1.3	11.6	1.3	10.3	2.9	28037.1	42241.8	47 32.6240	122 38.4875	47 32.6230	122 38.4893	light
Sinclair Inlet			2		1103	1.5/0.9	11.7	1.4	10.3	1.6	28037.1	42241.7	47 32.6239	122 38.4888			
			3		1114	1.5/0.9	11.7	1.5	10.2	1.6	28037.1	42241.7	47 32.6232	122 38.4905			
19	162	3	1	4-Jun-98	1235	1.8/1.1	13.3	2.1	11.2	0.7	28038.6	42242.0	47 32.8345	122 38.4888	47 32.8346	122 38.4893	light
Sinclair Inlet			2		1248	2.6/1.5	13.5	2.1	11.4	1.8	28038.6	42242.1	47 32.8353	122 38.4885			
			3		1259	2.2/1.1	13.6	2.2	11.4	2.9	28038.6	42242.1	47 32.8358	122 38.4876			
20	163	1	1	3-Jun-98	1100	1.9/1.2	12.2	1.8	10.4	2.8	28040.8	42239.7	47 32.7429	122 39.2436	47 32.7421	122 39.2456	light
Sinclair Inlet			2		1116	1.9/1.2	12.2	1.9	10.3	0.7	28040.8	42239.7	47 32.7419	122 39.2459			
20	164	2	1	3-Jun-98	1408	2.1/1.1	8.6	2.3	6.3	2.2	28044.9	42238.0	47 32.9401	122 39.9230	47 32.9405	122 39.9214	light
Sinclair Inlet			2		1422	2.0/1.0	8.6	2.3	6.3	2.4	28044.9	42238.0	47 32.9407	122 39.9238			
			3		1436	1.7/0.9	8.6	2.3	6.3	0.8	28044.9	42238.1	47 32.9409	122 39.9211			
20	165	3	4		1449	1.7/0.9	8.5	2.2	6.3	1.3	28044.9	42238.1	47 32.9399	122 39.9207	47 32.8347	122 39.9857	light
Sinclair Inlet			1	3-Jun-98	1148	1.8/1.0	10.8	2.1	8.7	1.4	28044.4	42237.7	47 32.8355	122 39.9860			
			2		1204	1.8/1.0	10.9	2.2	8.7	1.7	28044.3	42237.7	47 32.8339	122 39.9861			
			3		1215	1.8/1.0	10.9	2.2	8.7	1.2	28044.4	42237.8	47 32.8344	122 39.9848			
21	166	1	1	2-Jun-98	1330	1.9/1.1	18.3	2.2	16.1	2.5	28072.2	42244.3	47 36.5333	122 39.8080	47 36.5339	122 39.8062	heavy
Pt. Washington Narrows			2		1341	1.6/0.9	17.7	2.2	15.5	2.1	28072.1	42244.3	47 36.5329	122 39.8052			
			3		1350	1.6/0.9	18.0	2.2	15.8	0.4	28072.2	42244.2	47 36.5338	122 39.8059			
21	167	2	1	2-Jun-98	1420	1.8/1.0	8.2	2.1	6.1	1.7	28060.7	42241.9	47 35.0836	122 39.7808	47 35.0836	122 39.7822	heavy
Pt. Washington Narrows			2		1429	1.7/0.9	8.2	2.0	6.2	0.8	28060.8	42241.9	47 35.0833	122 39.7827			
			3		1439	1.7/0.9	8.3	2.0	6.3	1.0	28060.8	42241.9	47 35.0841	122 39.7827			
			4		1447	1.7/0.9	8.3	1.9	6.4	3.0	28060.7	42241.9	47 35.0824	122 39.7804			
21	168	3.2	1	3-Jun-98	0945	2.2/1.2	25.8	1.2	24.6	2.5	28061.7	42242.7	47 35.3011	122 39.5957	47 35.3011	122 39.5977	heavy
Pt. Washington Narrows			2		0959	2.5/1.3	26.2	1.3	24.9	0.6	28061.7	42242.7	47 35.3009	122 39.5980			
			3		1010	2.6/1.3	26.1	1.3	24.8	0.4	28061.7	42242.7	47 35.3012	122 39.5981			
22	169	1	1	2-Jun-98	0906	2.6/1.2	7.5	1.5	6.0	1.7	28088.4	42244.3	47 38.1431	122 40.7447	47 38.1437	122 40.7449	heavy
Dyes Inlet			2		0918	2.5/1.1	7.3	1.6	5.7	0.4	28088.4	42244.3	47 38.1439	122 40.7447			

Appendix B. Continued.

Stratum	Sample	Station	Deploy-ment No.	Date	GPS Time	GPS PDOP/HDOP	Stern Transd. Depth m.	Predicted Tide (m.): Nearest Station	Predicted Mudline Depth, m. (MLLW)	Distance to Station (m)	LORAN-C Yankee	LORAN-C Zulu (shaded =Best no.)	DGPS (Trimble NT300D) NAD 1983 Decimal Minutes Latitude	DGPS Longitude	Station Target NAD 1983 Decimal Minutes Latitude	Station Target Longitude	Van Veen Grab Type
			3		0925	2.6/1.2	7.3	1.6	5.7	1.4	28088.4	42244.3	47 38.1437	122 40.7438			
			4		0932	2.6/1.2	7.3	1.7	5.6	1.4	28088.4	42244.3	47 38.1441	122 40.7438			
			5		0939	2.6/1.2	7.3	1.7	5.6	0.9	28088.4	42244.3	47 38.1440	122 40.7442			
22	170	2	1	2-Jun-98	1142	1.5/0.9	13.2	2.3	10.9	1.1	28082.8	42238.0	47 36.7847	122 42.0803	47 36.7845	122 42.0794	light
Dyes Inlet			2		1159	1.8/1.0	13.3	2.3	11.0	1.3	28082.8	42238.0	47 36.7837	122 42.0795			
			3		1209	1.8/1.0	13.3	2.3	11.0	1.3	28082.8	42238.0	47 36.7847	122 42.0804			
22	171	3	1	2-Jun-98	1015	2.6/1.3	13.3	1.9	11.4	1.2	28087.4	42241.1	47 37.6436	122 41.5139	47 37.6429	122 41.5137	heavy
Dyes Inlet			2		1029	2.3/1.9	13.5	2.0	11.5	0.5	28087.4	42241.1	47 37.6430	122 41.5133			
			3		1038	2.2/1.2	13.5	2.0	11.5	2.6	28087.4	42241.1	47 37.6419	122 41.5151			
23	172	1	1	15-Jun-98	1124	1.8/1.0	152.0	1.7	150.3	1.0	28006.4	42288.5	47 35.6641	122 24.7604	47 35.6640	122 24.7597	heavy
Outer Elliott Bay			2		1142	1.5/0.9	152.0	1.5	150.5	0.7	28006.3	42288.4	47 35.6635	122 24.7601			
			3		1154	2.3/1.1	152.0	1.4	150.6	1.8	28006.4	42288.4	47 35.6629	122 24.7596			
23	173	2	1	15-Jun-98	1323	1.8/1.0	142.0	0.5	141.5	8.5	28007.5	42291.6	47 36.2214	122 23.9676	47 36.2243	122 23.9619	heavy
Outer Elliott Bay			2		1345	1.7/0.9	131.0	0.3	130.7	7.6	28007.5	42291.6	47 36.2235	122 23.9678			
			3		1358	1.7/0.9	134.0	1.2	132.8	2.4	28007.5	42291.7	47 36.2253	122 23.9612			
23	174	3	1	15-Jun-98	1436	1.8/1.1	41.0	0.0	41.0	1.7	28017.5	42294.0	47 37.4875	122 23.9904	47 37.4882	122 23.9909	heavy
Outer Elliott Bay			2		1452	2.6/1.5	39.4	0.0	39.4	2.2	28017.5	42293.9	47 37.4891	122 23.9898			
			3		1500	2.3/1.1	39.0	0.0	39.0	1.4	28017.5	42293.9	47 37.4889	122 23.9913			
			4		1514	3.1/1.2	40.0	-0.1	40.1	0.6	28017.5	42293.9	47 37.4882	122 23.9904			
23	175	4	1	15-Jun-98	1018	1.5/0.9	50.5	2.3	48.2	1.3	28002.2	42285.7	47 34.8764	122 25.2086	47 34.8770	122 25.2094	heavy
Outer Elliott Bay			2		1031	1.8/1.2	50.8	2.2	48.6	2.4	28002.1	42285.6	47 34.8783	122 25.2107			
			3		1042	2.1/1.2	50.5	2.1	48.4	1.2	28002.1	42285.7	47 34.8767	122 25.2084			
			4		1052	1.5/0.9	50.5	2.0	48.5	1.0	28002.1	42285.6	47 34.8769	122 25.2086			
24	176	1	1	16-Jun-98	0948	2.0/1.2	13.0	2.5	10.5	1.1	28019.4	42294.6	47 37.7506	122 23.9458	47 37.7506	122 23.9474	heavy
Shoreline Elliott Bay			2		0958	2.2/1.3	13.2	2.5	10.7	1.2	28019.4	42294.6	47 37.7500	122 23.9469			
			3		1008	2.1/1.3	12.5	2.5	10.0	2.4	28019.4	42294.6	47 37.7515	122 23.9461			
			4		1018	1.7/1.1	13.0	2.5	10.5	1.6	28019.4	42294.6	47 37.7497	122 23.9477			

Appendix B. Continued.

Stratum	Sample	Station	Deploy-ment No.	Date	GPS Time	GPS PDOP/ HDOP	Stern Transd. Depth m.	Predicted Tide (m.): Nearest Station	Predicted Mudline Depth, m. (MLLW)	Distance to Station (m)	LORAN-C Yankee	LORAN-C Zulu (shaded =Best no.)	DGPS (Trimble NT300D) NAD 1983 Decimal Minutes Latitude	DGPS Longitude	Station Target NAD 1983 Decimal Minutes Latitude	Station Target Longitude	Van Veen Grab Type
Location																	
24	177	2	1	16-Jun-98	1046	1.6/1.0	5.9	2.4	3.5	2.4	28021.7	42294.2	47 37.9421	122 24.1667	47 37.9413	122 24.1651	heavy
Shoreline Elliott Bay			2		1056	1.8/1.0	6.1	2.3	3.8	0.8	28021.7	42294.2	47 37.9409	122 24.1653			
			3		1106	1.9/1.0	6.0	2.3	3.7	2.0	28021.7	42294.2	47 37.9413	122 24.1635			
			4		1114	1.9/1.0	6.0	2.2	3.8	0.2	28021.7	42294.2	47 37.9413	122 24.1650			
24	178	3	1	16-Jun-98	1136	1.8/1.0	22.9	2.1	20.8	1.3	28016.4	42295.1	47 37.5486	122 23.6142	47 37.5479	122 23.6138	heavy
Shoreline Elliott Bay			2		1146	2.6/1.4	23.0	2.0	21.0	3.4	28016.4	42295.1	47 37.5472	122 23.6113			
			3		1155	3.5/1.5	22.9	2.0	20.9	1.2	28016.5	42295.1	47 37.5477	122 23.6131			
25	179	1	1	16-Jun-98	1314	2.9/1.2	27.3	1.3	26.0	1..5	28010.8	42298.2	47 37.4361	122 22.4457	47 37.4366	122 22.4450	heavy
Shoreline Elliott Bay			2		1325	3.5/1.1	27.0	1.2	25.8	0.9	28010.8	42298.2	47 37.4370	122 22.4445			
			3		1334	4.1/1.0	27.8	1.1	26.7	1.2	28010.8	42298.1	47 37.4367	122 22.4440			
25	180	2	1	17-Jun-98	1455	2.3/1.1	22.5	1.2	21.3	0.5	28012.4	42297.5	47 37.4891	122 22.7205	47 37.4889	122 22.7208	heavy
Shoreline Elliott Bay			2		1506	2.4/1.1	22.7	1.2	21.5	1.1	28012.4	42297.5	47 37.4887	122 22.7217			
			3		1516	2.3/1.1	22.5	1.1	21.4	1.3	28012.3	42297.4	47 37.4884	122 22.7200			
			4		1525	2.3/1.1	22.5	1.1	21.4	2.4	28012.4	42297.5	47 37.4876	122 22.7205			
25	181	3	1	16-Jun-98	1401	6.6/1.3	36.0	0.9	35.1	0.9	28003.7	42299.3	47 36.9025	122 21.7381	47 36.9020	122 21.7381	heavy
Shoreline Elliott Bay			2		1422	4.3/1.6	37.0	0.7	36.3	0.6	28003.7	42299.3	47 36.9020	122 21.7376			
			3		1434	2.4/1.2	37.0	0.7	36.3	3.1	28003.6	42299.2	47 36.9006	122 21.7368			
25	115	4	1	1-Jul-98	1543	1.8/1.0	12.3	1.2	11.1	0.9	28014.1	42297.7	47 37.6867	122 22.7625	47 37.6865	122 22.7632	heavy
Shoreline Elliott Bay			2		1558	2.0/1.1	13.0	1.1	11.9	1.6	28014.0	42297.7	47 37.6857	122 22.7635			
			3		1612	2.0/1.1	12.2	1.1	11.1	0.4	28014.1	42297.8	47 37.6867	122 22.7631			
			4		1625	2.0/1.1	12.2	1.1	11.1	0.9	28014.1	42297.8	47 37.6865	122 22.7639			
26	182	1.2	1	18-Jun-98	1426	1.6/0.9	37.6	2.1	35.5	2.8	27994.2	42301.2	47 36.2525	122 20.6480	47 36.2515	122 20.6497	heavy
Shoreline Elliott Bay			2		1442	2.2/1.1	39.0	2.1	36.9	0.9	27994.2	42301.1	47 36.2510	122 20.6496			
			3		1453	2.3/1.1	38.3	2.0	36.3	1.5	27994.2	42301.2	47 36.2522	122 20.6497			
26	183	2	1	18-Jun-98	1531	2.1/1.1	13.6	1.8	11.8	2.0	27993.2	42301.7	47 36.2393	122 20.4248	47 36.2399	122 20.4234	heavy
Shoreline Elliott Bay			2		1546	2.0/1.2	13.2	1.7	11.5	0.6	27993.2	42301.7	47 36.2395	122 20.4234			
			3		1556	2.5/1.8	13.5	1.6	11.9	1.9	27993.2	42301.8	47 36.2404	122 20.4247			
			4		1607	4.0/2.3	12.9	1.5	11.4	0.8	27993.2	42301.7	47 36.2395	122 20.4235			

Appendix B. Continued.

Stratum	Sample	Station	Deploy-ment No.	Date	GPS Time	GPS PDOP/HDOP	Stern Transd. Depth m.	Predicted Tide (m.): Nearest Station	Predicted Mudline Depth, m. (MLLW)	Distance to Station (m)	LORAN-C Yankee	LORAN-C Zulu (shaded =Best no.)	DGPS (Trimble NT300D) NAD 1983 Decimal Minutes Latitude	DGPS Longitude	Station Target NAD 1983 Decimal Minutes Latitude	Station Target Longitude	Van Veen Grab Type
26	184	3.5	1	19-Jun-98	0934	2.2/1.3	12.5	0.8	11.7	1.6	27993.7	42301.7	47 36.2798	122 20.4594	47 36.2806	122 20.4588	heavy
Shoreline Elliott Bay			2		0958	1.5/0.9	12.2	1.0	11.2	0.2	27993.6	42301.7	47 36.2807	122 20.4587			
			3		1006	2.5/1.4	11.8	1.0	10.8	2.5	27993.7	42301.7	47 36.2817	122 20.4601			
			4		1015	2.1/1.3	12.3	1.1	11.2	3.1	27993.5	42301.5	47 36.2821	122 20.4600			
			5		1026	2.0/1.2	13.8	1.2	12.6	3.0	27993.6	42301.7	47 36.2802	122 20.4612			
			6		1044	1.8/1.0	12.5	1.4	11.1	2.3	27993.6	42301.7	47 36.2797	122 20.4578			
			7		1053	2.1/1.2	13.0	1.5	11.5	1.3	27993.6	42301.7	47 36.2803	122 20.4597			
27	185	1	1	18-Jun-98	1021	1.8/1.2	158.0	1.9	156.1	1.4	28006.1	42295.3	47 36.5983	122 22.9217	47 36.5990	122 22.9213	light
Mid Elliott Bay			2		1044	1.8/1.0	158.0	2.0	156.0	1.9	28006.1	42295.3	47 36.5984	122 22.9224			
			3		1059	1.8/1.0	158.0	2.1	155.9	1.9	28006.1	42295.3	47 36.5982	122 22.9203			
			4		1116	1.7/1.0	158.0	2.2	155.8	4.2	28006.1	42295.3	47 36.6003	122 22.9184			
27	186	2	1	18-Jun-98	1134	1.7/1.0	37.5	2.3	35.2	2.5	28005.8	42299.1	47 37.0919	122 21.9206	47 37.0907	122 21.9217	light
Mid Elliott Bay			2		1156	2.3/1.1	39.2	2.4	36.8	0.8	28005.9	42299.0	47 37.0905	122 21.9212			
			3		1208	2.2/1.1	39.4	2.4	37.0	1.6	28005.9	42299.0	47 37.0899	122 21.9221			
			4		1219	2.0/1.1	38.6	2.4	36.2	0.5	28005.8	42299.1	47 37.0904	122 21.9215			
27	187	3	1	19-Jun-98	1343	2.0/1.0	105.0	2.6	102.4	2.5	27999.2	42299.0	47 36.4313	122 21.5396	47 36.4312	122 21.5416	light
Mid Elliott Bay			2		1405	2.2/1.1	104.0	2.6	101.4	1.9	27999.3	42299.0	47 36.4322	122 21.5415			
			3		1418	2.5/1.3	104.0	2.6	101.4	1.8	27999.3	42299.0	47 36.4321	122 21.5412			
27	188	4	1	19-Jun-98	1135	2.3/1.1	35.2	1.9	33.3	3.3	27995.0	42301.5	47 36.3634	122 20.6347	47 36.3618	122 20.6336	light
189			2		1153	2.3/1.1	35.9	2.0	33.9	2.7	27995.0	42301.5	47 36.3619	122 20.6314			
			3		1205	2.1/1.1	36.2	2.1	34.1	1.2	27995.1	42301.4	47 36.3624	122 20.6337			
			4		1216	2.0/1.1	36.2	2.2	34.0	1.5	27995.0	42301.4	47 36.3622	122 20.6325			
28	189	1	1	22-Jun-98	1105	2.5/1.3	14.4	-0.5	14.9	1.3	27996.6	42293.6	47 35.4307	122 22.8292	47 35.4308	122 22.8303	heavy
Mid Elliott Bay			2		1116	2.4/1.3	14.2	-0.4	14.6	0.4	27996.6	42293.6	47 35.4306	122 22.8302			
			3		1126	2.3/1.1	14.2	-0.4	14.6	1.3	27996.5	42293.6	47 35.4303	122 22.8297			
28	190	2	1	22-Jun-98	1231	1.6/0.9	6.5	0.3	6.2	1.9	28000.9	42293.5	47 35.8295	122 23.1034	47 35.8300	122 23.1048	heavy
Mid Elliott Bay			2		1240	2.0/1.1	5.9	0.4	5.5	2.8	28000.9	42293.4	47 35.8301.	122 23.1070			
			3		1247	2.0/1.1	6.6	0.5	6.1	1.3	28000.9	42293.5	47 35.8306	122 23.1034			
			4		1256	2.0/1.1	7.0	0.6	6.4	0.6	28000.9	42293.4	47 35.8303	122 23.1045			
28	191	3	1	19-Jun-98	1454	2.3/1.1	102.0	2.6	99.4	1.5	27999.1	42295.1	47 35.9049	122 22.5499	47 35.9052	122 22.5487	light
Mid Elliott Bay			2		1510	2.3/1.1	102.0	2.5	99.5	0.6	27999.1	42295.1	47 35.9050	122 22.5484			
			3		1524	2.2/1.1	101.0	2.5	98.5	0.9	27999.1	42295.1	47 35.9058	122 22.5486			

Appendix B. Continued.

Stratum	Sample	Station	Deploy-ment No.	Date	GPS Time	GPS PDOP/ HDOP	Stern Transd. Depth m.	Predicted Tide (m.): Nearest Station	Predicted Mudline Depth, m. (MLLW)	Distance to Station (m)	LORAN-C Yankee	LORAN-C Zulu (shaded =Best no.)	DGPS (Trimble NT300D) NAD 1983 Decimal Minutes Latitude	DGPS Longitude	Station Target NAD 1983 Decimal Minutes Latitude	Station Target Longitude	Van Veen Grab Type
28	192	4	1	22-Jun-98	0955	1.5/0.9	69.0	-0.6	69.6	3.8	27998.7	42297.3	47 36.1386	122 21.9568	47 36.1366	122 21.9574	light
Mid Elliott Bay			2		1012	1.2/1.7	69.0	-0.7	69.7	1.5	27998.6	42297.2	47 36.1359	122 21.9569			
			3		1025	1.5/0.9	69.0	-0.7	69.7	3.0	27998.8	42297.4	47 36.1376	122 21.9552			
29	193	1	1	23-Jun-98	0950	1.5/0.9	81.0	-0.5	81.5	3.1	27994.6	42299.0	47 35.9990	122 21.2517	47 35.9979	122 21.2538	light
Mid Elliott Bay			2		1004	1.5/0.9	80.0	-0.6	80.6	1.2	27994.6	42299.0	47 35.9975	122 21.2532			
			3		1017	1.5/0.9	80.0	-0.7	80.7	1.7	27994.6	42299.0	47 35.9976	122 21.2552			
29	194	2	1	23-Jun-98	1050	1.8/1.0	67.0	-0.8	67.8	2.6	27993.0	42300.1	47 36.0147	122 20.8404	47 36.0152	122 20.8385	light
Mid Elliott Bay			2		1104	1.7/0.9	66.0	-0.8	66.8	2.0	27993.0	42300.2	47 36.0144	122 20.8395			
			3		1114	1.7/0.9	67.0	-0.8	67.8	1.3	27993.0	42300.2	47 36.0146	122 20.8384			
29	195	3	1	23-Jun-98	1139	2.2/1.1	77.0	-0.7	77.7	1.2	27996.2	42297.8	47 35.9743	122 21.6628	47 35.9747	122 21.6620	light
Mid Elliott Bay			2		1155	2.0/1.1	77.0	-0.6	77.6	2.7	27996.2	42297.7	47 35.9740	122 21.6604			
			3		1207	2.4/1.5	77.0	-0.6	77.6	0.9	27996.2	42297.9	47 35.9743	122 21.6619			
29	196	4	1	23-Jun-98	1325	1.7/0.9	72.0	0.4	71.6	2.4	27994.0	42299.9	47 36.0719	122 20.9790	47 36.0731	122 20.9792	light
Mid Elliott Bay			2		1341	2.1/1.1	72.0	0.6	71.4	1.6	27994.1	42299.9	47 36.0729	122 20.9780			
			3		1352	2.4/1.2	72.0	0.7	71.3	1.2	27994.1	42299.9	47 36.0727	122 20.9782			
30	197	1	1	24-Jun-98	1301	1.7/1.0	8.6	-0.5	9.1	2.8	27990.6	42295.9	47 35.1816	122 21.8227	47 35.1826	122 21.8243	heavy
West Harbor Island			2		1314	1.9/1.0	8.6	-0.4	9.0	0.5	27990.6	42296.0	47 35.1825	122 21.8246			
			3		1321	1.9/1.0	11.6	-0.3	11.9	3.7	27990.6	42295.9	47 35.1825	122 21.8213			
			4		1338	2.1/1.1	10.1	-0.1	10.2	3.3	27990.6	42296.0	47 35.1810	122 21.8233			
			5		1351	2.5/1.2	11.3	0.1	11.2	5.9	27990.6	42296.0	47 35.1833	122 21.8197			
			6		1359	1.8/1.1	9.7	0.2	9.5	3.1	27990.6	42296.0	47 35.1839	122 21.8228			
30	198	2	1	24-Jun-98	1517	2.1/1.2	49.0	1.4	47.6	1.6	27992.1	42295.6	47 35.2934	122 21.9938	47 35.2925	122 21.9933	heavy
West Harbor Island			2		1528	2.0/1.2	47.0	1.6	45.4	0.6	27992.1	42295.6	47 35.2927	122 21.9936			
			3		1539	3.9/2.3	48.0	1.8	46.2	3.2	27992.1	42295.6	47 35.2939	122 21.9917			
			4		1554	4.0/2.3	49.0	2.0	47.0	1.5	27992.1	42295.6	47 35.2918	122 21.9927			
30	199	3	1	24-Jun-98	1431	2.3/1.1	14.2	0.7	13.5	0.9	27991.0	42295.8	47 35.1995	122 21.9022	47 35.1999	122 21.9018	heavy
West Harbor Island			2		1441	2.4/1.1	14.3	0.8	13.5	2.8	27991.0	42295.8	47 35.2014	122 21.9015			
			3		1452	2.3/1.1	14.7	1.0	13.7	1.1	27991.0	42295.8	47 35.2003	122 21.9025			
30	114	4	1	1-Jul-98	1444	2.1/1.2	20.4	1.5	18.9	0.0	27984.7	42295.3	47 34.5267	122 21.6423	47 34.5267	122 21.6423	heavy
West Harbor Island			2		1455	2.2/1.4	20.3	1.4	18.9	2.1	27984.7	42295.3	47 34.5271	122 21.6439			
			3		1508	4.4/2.3	20.2	1.4	18.8	1.7	27984.7	42295.3	47 34.5259	122 21.6424			

Appendix B. Continued.

Stratum	Sample	Station	Deploy-ment No.	Date	GPS Time	GPS PDOP/ HDOP	Stern Transd. Depth m.	Predicted Tide (m.): Nearest Station	Predicted Mudline Depth, m. (MLLW)	Distance to Station (m)	LORAN-C Yankee	LORAN-C Zulu	DGPS (Trimble NT300D) NAD 1983 Decimal Minutes Latitude	DGPS Longitude	Station Target NAD 1983 Decimal Minutes Latitude	Station Target Longitude	Van Veen Grab Type
Location												=Best no.					
31	200	1	1	24-Jun-98	1027	2.1/1.0	15.3	-0.4	15.7	0.1	27985.2	42298.8	47 35.0786	122 20.7475	47 35.0786	122 20.7475	heavy
East Harbor Island			2		1042	2.1/1.0	15.4	-0.6	16.0	1.7	27985.3	42298.8	47 35.0790	122 20.7463			
			3		1053	2.0/1.0	15.4	-0.6	16.0	1.3	27985.2	42298.8	47 35.0788	122 20.7465			
31	201	2.2	1	24-Jun-98	1119	2.9/1.2	12.4	-0.8	13.2	0.4	27983.7	42298.9	47 34.9573	122 20.6066	47 34.9571	122 20.6067	heavy
East Harbor Island			2		1136	2.6/1.1	12.1	-0.8	12.9	0.4	27983.7	42299.0	47 34.9572	122 20.6065			
			3		1147	2.3/1.1	12.1	-0.9	13.0	2.1	27983.7	42298.9	47 34.9574	122 20.6051			
31	202	3	1	24-Jun-98	0941	1.6/1.0	14.8	0.1	14.7	0.9	27980.0	42297.9	47 34.4598	122 20.6004	47 34.4596	122 20.5997	light
East Harbor Island			2		0949	1.6/1.0	14.8	0.0	14.8	2.5	27979.9	42298.0	47 34.4585	122 20.6009			
			3		1000	2.0/1.4	14.5	-0.2	14.7	1.8	27979.9	42297.8	47 34.4593	122 20.6010			
32	203	1	1	22-Jun-98	1330	1.7/0.9	5.1	1.2	3.9	2.6	27974.8	42296.0	47 33.6831	122 20.8466	47 33.6844	122 20.8461	heavy
Duwamish			2		1342	2.1/1.1	5.4	1.4	4.0	0.6	27974.8	42296.0	47 33.6843	122 20.8457			
			3		1353	2.2/1.1	5.6	1.5	4.1	1.6	27974.8	42296.0	47 33.6836	122 20.8466			
32	204	2	1	22-Jun-98	1417	2.0/1.1	6.2	1.9	4.3	0.7	27974.1	42296.4	47 33.6556	122 20.7059	47 33.6554	122 20.7053	heavy
Duwamish			2		1427	2.2/1.1	6.5	2.0	4.5	1.9	27974.1	42296.4	47 33.6546	122 20.7062			
			3		1438	2.3/1.1	5.6	2.2	3.4	1.6	27974.0	42296.4	47 33.6546	122 20.7047			
32	205	3	1	23-Jun-98	1430	2.3/1.1	9.0	1.4	7.6	0.7	27964.7	42296.0	47 32.7063	122 20.2129	47 32.7066	122 20.2126	light
Duwamish			2		1443	2.4/1.1	8.6	1.6	7.0	2.1	27964.7	42296.1	47 32.7059	122 20.2113			
			3		1452	2.3/1.1	8.7	1.7	7.0	2.0	27964.7	42296.1	47 32.7070	122 20.2110			

Appendix C

Field notes for the 1998 central Puget Sound sampling stations.

Appendix C. Field notes for the 1998 central Puget Sound sampling stations.

Stratum	Station	Sample	Station Description	Salinity (ppt)	Temp-erature (°c)	Sediment Type	Sediment Color	Sediment Odor and intensity	Penetration Depth (cm)	RPD (cm)
1	1	106	suburban	32	11.5	sandy silt clay wood	gray	NR	16.5	>5
1	2	107	suburban	34	12	silt-clay	olive gray	none	16.0	4
1	3	108	suburban	32	13	silt-clay	olive gray	NR	11.0	4.5
2	1	109	suburban	33	12	sand shell	gray brown	none	7.0	mixed
2	2	110	suburban	34	11	sand	gray brown	none	11.0	mixed
2	3	111	suburban	32	12	silty sand	gray brown	none	12.0	mixed
4	4	112	rural	32	13	silty sand	gray brown	none	5.0	mixed
4	2	116	suburban	27	13	sand	gray	none	13.0	mixed
4	3	117	suburban	30	13	sand	gray	none	7.0	none
5	1	118	suburban	30	12	silt-clay	olive gray	none	17.0	4
5	2	119	suburban	30	12	sand	gray brown	none	10.0	mixed
5	3	120	suburban	31	13	silty sand	gray brown	none	8.0	mixed
6	1	121	urban	31	14	sand	gray brown	none	10.0	mixed
6	2	122	urban/suburban	31	12	silt-clay shell	olive gray	strong sulfur	17.0	5
6	6	123	urban/suburban	31	12	silt-clay shell	olive gray	none	17.0	2
7	1	124	suburban	31	11.5	silt-clay	olive brown	none	16.0	mixed
7	2	125	suburban	30	11.5	silt-clay	olive brown	none	16.0	mixed
7	3	126	suburban	32	12	silty sand	gray brown	none	NR	none
8	4	113	suburban	30	13	silt-clay	olive gray	slight sulfur	15.0	4
8	1	127	suburban	34	11	silt-clay	olive gray	none	17.0	NR
8	2	128	suburban	31	11.5	silt-clay	gray	none	17.0	7
8	3	129	suburban	30	11	gravel silt clay	gray brown	moderate sulfur	17.0	mixed
9	1	130	NR	33	13	sand silt-clay	gray brown	petroleum strong	10.0	3
9	2	131	suburban	31	14	silt-clay	olive gray	strong sulfur and petroleum	16.0	4
9	3	132	NR	31	12	silty sand	gray brown	moderate sulfur and petroleum	10.0	0
10	1	133	suburban	32	11	sand shell	brown	none	12.0	none
10	2	134	suburban	32	11	sand	brown	none	8.5	none
10	3	135	suburban	32	11	sand plant frags	brown	none	8.0	none
11	1	136	suburban	31	11	silt-clay	olive gray	none	17.0	4
11	2	137	suburban	30	12	silt-clay	olive gray	slight sulfur	17.0	4
11	3	138	suburban	31	12	silt-clay	olive gray	none	17.0	4
12	1	139	suburban	30	11	silt-clay	olive gray	NR	15.0	4
12	2	140	suburban	31	11	silt-clay	olive gray	NR	17.0	2
12	3	141	urban/residential	31	11	cobbles gravel sand	gray brown	strong sulfur sewage	8.0	3
13	1	142	suburban	30	14	silt-clay	olive over black	strong sulfur	17.0	>3

Appendix C. Continued.

Stratum	Station	Sample	Station Description	Salinity (ppt)	Temp-erature (°c)	Sediment Type	Sediment Color	Sediment Odor and intensity	Penetration Depth (cm)	RPD (cm)
13	2	143	suburban	31	14.5	silt-clay	olive over black	strong sulfur	17.0	2
13	3	144	suburban	31	14	silt-clay	NR	strong sulfur	17.0	2
14	1	145	suburban	30	14	sand silt-clay	gray brown	slight sulfur	10.0	none
14	2	146	suburban	30	14	silt-clay	olive gray	strong sulfur	15.0	>3
14	3	147	suburban	31	14	sand shell	gray	moderate sulfur	7.0	none
15	1	148	NR	32	13.5	silt-clay	olive gray	moderate sulfur	16.0	2
15	2	149	suburban	31	14	sand	gray brown	none	NR	none
15	3	150	suburban	31	12.5	silt-clay	gray brown	none	16.0	NR
16	1	151	suburban	31	12	silt-clay	olive gray	none	16.0	3
16	2	152	suburban	31	13	silty sand	olive gray	NR	14.0	3
16	3	153	suburban	31	12	silt-clay	olive gray	NR	16.0	2.5
17	1	154	suburban	31	13	sand	gray	NR	6.0	none
17	2	155	suburban	31	14	sand	gray brown	NR	10.0	none
17	3	156	suburban	30	13	sand	gray brown	none	NR	none
18	1	157	suburban	30	12	sand	brown	none	10.0	none
18	2	158	suburban	30	12.5	sand plant frags	brown	none	8.0	none
18	3	159	urban	31	13	cobbles gravel sand shell	brown	none	8.0	none
19	1	160	suburban	31	12	silt-clay	black olive	strong sulfur	17.0	NR
19	2	161	urban	31	12	silt-clay wood shell	olive over black	strong sulfur	17.0	0.2
19	3	162	urban	30	12	silt-clay wood	olive over black	moderate sulfur	17.0	NR
20	1	163	NR	30	13	silt-clay	olive gray	strong sulfur	17.0	2.5
20	2	164	suburban	30	13	silt-clay	gray	moderate sulfur	17.0	2
20	3	165	urban	31	12.5	silt-clay	olive gray	strong sulfur	17.0	5
21	1	166	suburban	30	14	sand	gray	none	10.0	none
21	2	167	suburban/residential	31	14	silty sand	gray	none	10.0	none
21	3	168	suburban	31	13	sandy silt clay	NR	strong sulfur	15.0	2
22	2	169	suburban	31	13	sand	gray brown	NR	10.0	none
22	2	170	suburban	30	13	silt-clay	olive gray	strong sulfur	17.0	5
22	3	171	suburban	30	13	sandy silt clay	olive brown	strong sulfur	17.0	3
23	1	172	urban	30	11	silt-clay	olive gray	none	17.0	6
23	2	173	urban	30	11.5	silt-clay	olive gray	none	17.0	4
23	3	174	urban	30	12	slag pieces gravel sand	gray brown	none	7.0	none
23	4	175	urban	31	13	very corse sand	gray brown	sulfur one grab only	6.0	none
24	1	176	urban	31	13	sand	gray	none	9.0	mixed
24	2	177	urban	30	14	sand	gray	none	5.0	mixed
24	3	178	urban	30	12	sand	gray	none	7.0	mixed
25	4	115	urban residential	30	13	silty sand wood	gray black	petroleum strong	10.0	1

Appendix C. Continued.

Stratum	Station	Sample	Station Description	Salinity (ppt)	Temp-erature (°c)	Sediment Type	Sediment Color	Sediment Odor and intensity	Penetration Depth (cm)	RPD (cm)
25	1	179	urban	30	12	silty sand silt-clay	gray brown	strong sulfur	17.0	1
25	2	180	urban	30	14	sand silt-clay wood	gray	none	12.0	mixed
25	3	181	urban	30	12	sandy silt clay	gray brown	none	17.0	1
26	1	182	urban	30	12	sandy silt clay wood	gray brown	none	14.0	4
26	2	183	urban	30	13	sand wood plant frags	gray black	none	10.0	none
26	3	184	urban	30	12	sand shell plant frags	brown over gray	none	8.0	2
27	1	185	urban	30	11	silt clay	olive gray	NR	17.0	4
27	2	186	urban	30	12	sand silt clay	gray brown	none	14.0	2
27	3	187	urban	30	11	silt-clay	brown over gray	none	17.0	>4
27	4	188	urban	32	11	silt clay shell	brown over gray	none	17.0	>4
28	1	189	urban	30	11	sand silt clay	gray brown	NR	10.0	NR
28	2	190	urban	31	14	sand	gray brown	NR	14.0	NR
28	3	191	urban	30	11.5	silt clay	brown over gray	none	17.0	>4
28	4	192	urban	30	11.5	gravel sand	gray brown	NR	15.0	NR
29	1	193	urban	27	11	sand silt clay	brown over dark olive	NR	16.5	NR
29	2	194	urban	30	11.5	sand silt clay	brown	NR	17.5	0
29	3	195	urban	30	11	sand silt clay	brown	NR	16.0	0
29	4	196	urban	30	11	silt clay	gray	NR	17.0	0
30	4	114	urban/industrial	26	14	silt clay	gray black	NR	10.0	1
30	1	197	urban/industrial	30	13	sand silt clay	gray brown	NR	6.0	NR
30	2	198	urban/industrial	30	13	sand silt clay wood	brown	NR	13.5	0
30	3	199	urban/industrial	30	13	sand silt clay	gray brown	NR	10.0	2
31	1	200	urban/industrial	30	13	NR	NR	NR	13.5	NR
31	2	201	urban/industrial	31	12	silt clay	brown over black	NR	14.5	0.5
31	3	202	urban/industrial	30	12	silt clay	olive brown	NR	9.0	0
32	1	203	urban/industrial	27	13	sand silt clay	olive gray	NR	16.0	2
32	2	204	urban/industrial	25	14	sand silt clay	olive brown over black	moderate sulfur and petroleum	12.0	1
32	3	205	NR	25	14	silt clay wood	dark brown	NR	17.0	0

NR = not recorded
RPD = redox potential depth

Appendix D

Chemistry data summary.

Table 1. Grain size distribution for the 1998 central Puget Sound sampling stations (tabular form).

Table 2. Total organic carbon, temperature, and salinity measurements for the 1998 central Puget Sound sampling stations.

Table 3. Summary statistics for metals and organic chemicals for the 1998 central Puget Sound sampling stations.

Figure 1. Grain size distribution for the 1998 central Puget Sound sampling stations (histograms).

Appendix D, Table 1. Grain size distribution for the 1998 central Puget Sound sampling stations (grain size in fractional percent)[1,2]

Stratum	Sample	Station	% Solids[3]	% Gravel >2000 mm	% Very Coarse Sand 2000-1000 mm	% Coarse Sand 1000-500 mm	% Medium Sand 500-250 mm	% Fine Sand 250-125 mm	% Very Fine Sand 125-62.5 mm	Total % Sand 2000-62.5 mm	% Silt 62.5-3.9 mm	% Clay <3.9 mm	% Fines (Silt-Clay)
1	106	1	47	3.0	0	1	4	26	20	51.1	36	10	46
South Port	107	2	42	4.1	2	3	5	17	12	38.5	37	21	57
Townsend	108	3	35	0.4	1	0	1	1	3	5.9	81	12	94
2	109	1	71	3.4	1	1	16	57	12	86.6	6	4	10
Port Townsend	110	2	75	0.1	0	12	55	27	2	96.5	1	2	3
	111	3	62	0.2	0	0	1	20	43	64.9	22	13	35
4	112	4	56	4.7	2	2	5	34	24	67.5	19	9	28
South Admiralty	116	2	74	0.0	0	0	35	51	9	95.4	3	2	5
Inlet	117	3	72	1.3	6	8	19	47	14	94.5	3	2	4
5	118	1	32	0.0	0	0	1	3	4	8.1	71	21	92
Possession Sound	119	2	73	0.0	0	0	27	61	5	93.7	2	4	6
	120	3	73	0.0	0	0	28	63	5	95.3	2	3	5
6	121	1	68	0.0	0	2	55	34	5	95.3	2	3	5
Central Basin	122	2	39	0.0	0	0	0	2	12	14.3	55	31	86
	123	3	41	0.0	0	0	1	2	11	13.5	57	29	86
7	124	1	68	0.0	0	1	10	24	40	75.3	18	6	25
Port Madison	125	2	63	0.0	0	1	14	47	12	73.6	19	8	26
	126	3	73	0.1	0	0	7	60	19	86.0	10	4	14

Appendix D. Table 1. Continued.

Stratum	Sample	Station	% Solids[3]	% Gravel >2000 mm	% Very Coarse Sand 2000-1000 mm	% Coarse Sand 1000-500 mm	% Medium Sand 500-250 mm	% Fine Sand 250-125 mm	% Very Fine Sand 125-62.5 mm	Total % Sand 2000-62.5 mm	% Silt 62.5-3.9 mm	% Clay <3.9 mm	% Fines (Silt-Clay)
8	113	4	38	0.0	0	0	3	3	8	14.9	59	26	85
West Point	127	1	36	0.0	0	0	1	1	7	9.8	64	27	90
	128	2	38	0.0	0	1	2	6	17	25.9	48	26	74
	129	3	50	3.9	4	6	12	20	11	53.7	27	15	42
9	130	1	49	0.3	0	2	10	24	20	55.9	33	10	44
Eagle Harbor	131	2	40	0.2	0	0	1	5	13	19.8	67	13	80
	132	3	65	0.3	0	4	24	36	14	79.2	13	8	20
10	133	1	63	0.1	0	1	4	31	44	80.7	10	9	19
Central Basin	134	2	66	0.0	0	0	3	44	39	86.5	6	7	13
	135	3	68	0.2	0	0	4	67	18	89.1	4	6	11
11	136	1	34	0.3	0	0	2	1	3	6.2	65	29	94
Central Basin	137	2	35	0.0	0	2	6	2	4	14.9	59	26	85
	138	3	35	0.1	0	0	3	6	8	19.0	50	31	81
12	139	1	41	0.0	0	1	2	22	21	45.8	29	25	54
East Passage	140	2	26	0.0	0	0	0	0	1	2.3	57	40	98
	141	3	79	59.2	10	6	6	5	2	29.2	5	6	12
13	142	1	27	0.9	0	0	1	1	3	5.1	76	18	94
Liberty Bay	143	2	29	0.0	1	1	1	2	6	10.5	73	16	90
	144	3	26	0.0	0	0	0	1	2	3.1	71	26	97
14	145	1	73	0.4	4	11	31	40	4	89.4	6	4	10
Keyport	146	2	28	0.0	0	0	1	2	5	7.9	74	18	92
	147	3	72	1.7	4	13	34	33	5	88.9	6	4	9
15	149	2	75	0.6	1	11	46	33	3	93.8	3	3	6
North West	150	3	41	0.6	0	1	2	12	33	48.3	40	11	51

Appendix D. Table 1. Continued.

Stratum	Sample	Station	% Solids[3]	% Gravel >2000 mm	% Very Coarse Sand 2000-1000 mm	% Coarse Sand 1000-500 mm	% Medium Sand 500-250 mm	% Fine Sand 250-125 mm	% Very Fine Sand 125-62.5 mm	Total % Sand 2000-62.5 mm	% Silt 62.5-3.9 mm	% Clay <3.9 mm	% Fines (Silt-Clay)
Bainbridge	148*	1	28	0.0	0	1	2	2	5	9.6	71	20	90
16	151	1	27	0.0	0	0	1	1	2	4.6	73	22	95
South West	152	2	62	2.9	0	0	7	43	25	74.9	11	11	22
Bainbridge	153	3	28	0.0	0	0	1	3	8	13.1	66	21	87
17	154	1	76	5.1	5	15	31	34	5	90.8	2	2	4
Rich Passage	155	2	76	1.1	3	13	41	37	3	96.6	1	2	2
	156	3	70	0.0	0	4	42	41	5	90.7	4	5	9
18	157	1	66	0.2	0	0	5	56	22	84.2	7	9	16
Port Orchard	158	2	73	0.4	1	4	24	53	9	90.5	4	5	9
	159	3	73	18.6	5	6	21	32	8	73.0	5	4	8
19	160	1	24	0.9	0	0	0	1	1	3.3	77	19	96
Sinclair Inlet	161	2	26	0.1	0	0	0	1	5	6.9	80	13	93
	162	3	30	0.0	1	1	2	3	4	9.9	74	16	90
20	164	2	37	1.3	1	0	0	1	6	8.9	78	12	90
Sinclair Inlet	165	3	35	1.0	0	0	1	2	9	12.2	74	13	87
	163*	1	27	0.4	0	0	0	1	1	3.5	83	13	96
21	166	1	73	0.3	0	6	39	42	5	92.7	6	1	7
Pt. Washington	167	2	72	0.0	0	4	22	47	19	92.1	4	4	8
Narrows	168	3	54	0.5	1	1	4	28	30	64.1	24	12	35

Appendix D. Table 1. Continued.

Stratum	Sample	Station	% Solids[3]	% Gravel >2000 mm	% Very Coarse Sand 2000-1000 mm	% Coarse Sand 1000-500 mm	% Medium Sand 500-250 mm	% Fine Sand 250-125 mm	% Very Fine Sand 125-62.5 mm	Total % Sand 2000-62.5 mm	% Silt 62.5-3.9 mm	% Clay <3.9 mm	% Fines (Silt-Clay)
22	169	1	75	0.3	2	10	32	42	6	91.4	5	4	8
Dyes Inlet	170	2	30	0.0	0	1	1	1	4	6.6	76	18	93
	171	3	29	0.0	1	1	1	4	5	11.7	71	17	88
23	173	2	40	0.4	1	4	11	12	10	37.5	41	21	62
Outer Elliott Bay	174	3	76	0.6	0	1	31	50	10	91.9	4	4	8
	175	4	74	2.1	3	11	22	44	12	91.9	3	3	6
	172*	1	33	0.0	0	1	1	1	5	8.1	61	31	92
24	176	1	69	0.8	1	7	44	32	4	89.2	6	4	10
Shoreline Elliott	177	2	73	0.3	0	1	32	55	6	95.0	3	2	5
Bay	178	3	75	0.2	0	2	42	37	8	89.2	6	4	11
25	115	4	55	0.9	0	0	6	27	20	53.6	28	17	46
Shoreline Elliott	179	1	60	0.3	0	1	5	22	24	52.2	38	10	47
Bay	180	2	66	1.7	0	1	12	31	26	69.9	22	7	28
	181	3	52	9.5	6	6	11	11	4	37.7	38	14	53
26	182	1	50	2.3	2	2	7	8	6	24.6	56	17	73
Shoreline Elliott	183	2	66	0.7	4	17	45	18	3	87.5	7	5	12
Bay	184	3	61	4.2	3	7	32	24	7	72.0	13	11	24
27	185	1	33	0.0	0	1	5	4	4	15.0	57	28	85
Mid Elliott Bay	186	2	59	1.2	2	3	17	30	11	61.9	29	8	37
	188	4	45	1.1	1	2	7	7	7	23.8	57	18	75
	187*	3	35	0.0	0	0	3	5	4	13.5	57	30	86

Appendix D. Table 1. Continued.

Stratum	Sample	Station	% Solids[3]	% Gravel >2000 mm	% Very Coarse Sand 2000-1000 mm	% Coarse Sand 1000-500 mm	% Medium Sand 500-250 mm	% Fine Sand 250-125 mm	% Very Fine Sand 125-62.5 mm	Total % Sand 2000-62.5 mm	% Silt 62.5-3.9 mm	% Clay <3.9 mm	% Fines (Silt-Clay)
28	189	1	63	0.2	0	1	9	36	30	76.2	19	4	24
Mid Elliott Bay	190	2	71	0.6	0	1	27	59	9	96.5	1	1	3
	191	3	38	0.1	1	2	5	6	10	24.9	52	23	75
	192	4	57	10.4	6	8	17	15	7	53.2	27	10	36
29	193	1	53	0.2	0	1	11	31	22	66.4	27	6	33
Mid Elliott Bay	194	2	38	0.2	0	0	1	2	4	6.9	69	23	93
	195	3	52	0.0	0	1	8	27	23	58.9	32	9	41
	196	4	35	0.0	0	0	1	1	3	5.5	68	26	94
30	114	4	48	0.0	0	1	5	8	9	22.8	53	25	77
West Harbor	197	1	64	2.5	3	10	30	28	13	83.9	10	4	14
Island	198	2	64	2.5	3	8	18	16	21	65.6	24	8	32
	199	3	56	0.0	0	0	2	14	27	43.9	43	13	56
31	200	1	50	0.1	0	1	6	20	18	45.2	36	18	55
East Harbor Island	201	2	50	0.0	0	1	5	9	10	25.5	59	15	74
	202*	3	40	0.0	0	1	5	6	5	17.8	58	24	82
32	203	1	52	0.1	0	2	14	13	7	37.0	45	18	63
Duwamish	204	2	63	0.4	2	14	35	18	6	75.3	17	7	24
	205	3	57	0.6	3	15	16	4	5	43.1	45	11	56

[1] Organics included. Corrected for dissolved solids.

[2] Particle size intervals based on US Army Corps of Engineers and Wentworth Soil Classification Systems.

[3] Percent Solids measured according to Plum, 1981. EPA/CE-81-1.

* Mean of three lab replicates.

Appendix D. Table 2. Total organic carbon, temperature, and salinity measurements for the 1998 central Puget Sound sampling stations.

Stratum	Station	Sample	Location	Salinity (ppt)	Temperature (°c)	% TOC
1	1	106	South Port Townsend	32	11.5	2.15
1	2	107		34	12	2.13
1	3	108		32	13	2.13
2	1	109	Port Townsend	33	12	0.38
2	2	110		34	11	0.11
2	3	111		32	12	0.72
4	4	112	South Admiralty Inlet	32	13	0.75
4	2	116		27	13	0.17
4	3	117		30	13	0.21
5	1	118	Possession Sound	30	12	2.03
5	2	119		30	12	0.22
5	3	120		31	13	0.21
6	1	121	Central Basin	31	14	0.19
6	2	122		31	12	1.73
6	6	123		31	12	1.67
7	1	124	Port Madison	31	11.5	0.55
7	2	125		30	11.5	0.48
7	3	126		32	12	0.24
8	4	113	West Point	30	13	1.79
8	1	127		34	11	2.02
8	2	128		31	11.5	1.86
8	3	129		30	11	1.02
9	1	130	Eagle Harbor	33	13	1.74
9	2	131		31	14	2.41
9	3	132		31	12	0.65
10	1	133	Central Basin	32	11	0.51
10	2	134		32	11	0.42

Appendix D. Table 2. Continued.

Stratum	Station	Sample	Location	Salinity (ppt)	Temperature (°c)	% TOC
10	3	135		32	11	0.76
11	1	136	Central Basin	31	11	1.49
11	2	137		30	12	1.54
11	3	138		31	12	1.54
12	1	139	East Passage	30	11	1.35
12	2	140		31	11	2.34
12	3	141		31	11	0.25
13	1	142	Liberty Bay	30	14	3.21
13	2	143		31	14.5	3.03
13	3	144		31	14	3.56
14	1	145	Keyport	30	14	0.39
14	2	146		30	14	3.17
14	3	147		31	14	0.41
15	1	148	North West Bainbridge	32	13.5	3.12
15	2	149		31	14	0.32
15	3	150		31	12.5	1.96
16	1	151	South West Bainbridge	31	12	3.16
16	2	152		31	13	0.44
16	3	153		31	12	2.37
17	1	154	Rich Passage	31	13	0.17
17	2	155		31	14	0.16
17	3	156		30	13	0.33
18	1	157	Port Orchard	30	12	0.52
18	2	158		30	12.5	0.32
18	3	159		31	13	0.41
19	1	160	Sinclair Inlet	31	12	4.16
19	2	161		31	12	3.29
19	3	162		30	12	3.13

Appendix D. Table 2. Continued.

Stratum	Station	Sample	Location	Salinity (ppt)	Temperature (°c)	% TOC
20	1	163	Sinclair Inlet	30	13	3.37
20	2	164		30	13	2.31
20	3	165		31	12.5	2.41
21	1	166	Port Washington Narrows	30	14	0.29
21	2	167		31	14	0.31
21	3	168		31	13	1.47
22	2	169	Dyes Inlet	31	13	0.27
22	2	170		30	13	3.38
22	3	171		30	13	2.99
23	1	172	Outer Elliott Bay	30	11	1.67
23	2	173		30	11.5	1.15
23	3	174		30	12	0.13
23	4	175		31	13	0.32
24	1	176	Shoreline Elliott Bay	31	13	0.33
24	2	177		30	14	0.15
24	3	178		30	12	0.16
25	4	115	Shoreline Elliott Bay	30	13	1.55
25	1	179		30	12	0.64
25	2	180		30	14	0.48
25	3	181		30	12	1.13
26	1	182	Shoreline Elliott Bay	30	12	1.63
26	2	183		30	13	0.72
26	3	184		30	12	2.78
27	1	185	Mid Elliott Bay	30	11	1.55
27	2	186		30	12	0.71
27	3	187		30	11	2.03
27	4	188		32	11	2.43
28	1	189	Mid Elliott Bay	30	11	0.84
28	2	190		31	14	0.19

Appendix D. Table 2. Continued.

Stratum	Station	Sample	Location	Salinity (ppt)	Temperature (°c)	% TOC
28	3	191		30	11.5	1.83
28	4	192		30	11.5	1.07
29	1	193	Mid Elliott Bay	27	11	1.55
29	2	194		30	11.5	2.1
29	3	195		30	11	1.85
29	4	196		30	11	2.14
30	4	114	West Harbor Island	26	14	1.78
30	1	197		30	13	0.68
30	2	198		30	13	1.26
30	3	199		30	13	1.7
31	1	200	East Harbor Island	30	13	1.65
31	2	201		31	12	1.99
31	3	202		30	12	2.54
32	1	203	Duwamish	27	13	1.5
32	2	204		25	14	1.13
32	3	205		25	14	1.33
			min	25.0	11.0	0.1
			max	34.0	14.5	4.2
			mean	30.5	12.4	1.4
			median	30.0	12.0	1.4

Appendix D, Table 3. 1998 summary statistics for metal and organic chemicals for the 1998 central Puget Sound sampling stations.

COMPOUND (unit of measure)	MEAN	MEDIAN	MINIMUM	MAXIMUM	RANGE	N	NO. OF NON-DETECTED VALUES	NO. OF MISSING VALUES
METALS (ppm, mg/kg dry wt)								
Ancillary Metals								
Aluminum*	12,452.29	11,200.00	5,280.00	21,000.00	15,720.00	105	0	0
Aluminum**	63,897.12	67,400.00	18,000.00	91,600.00	73,600.00	104	1	0
Barium*	33.47	33.00	7.80	119.00	111.20	105	0	0
Barium**	383.73	389.00	212.00	576.00	364.00	104	1	0
Calcium*	5,389.33	5,040.00	2,540.00	15,200.00	12,660.00	105	0	0
Calcium**	19,802.50	19,100.00	7,070.00	36,800.00	29,730.00	104	1	0
Cobalt*	6.97	6.93	2.80	15.40	12.60	105	0	0
Cobalt**	10.40	10.00	4.20	24.90	20.70	104	1	0
Iron*	18,559.43	19,600.00	7,160.00	30,400.00	23,240.00	105	0	0
Iron**	30,150.96	32,350.00	14,400.00	56,400.00	42,000.00	104	1	0
Magnesium*	7,159.81	7,020.00	3,360.00	12,200.00	8,840.00	105	0	0
Magnesium**	11,903.17	12,700.00	2,540.00	18,300.00	15,760.00	104	1	0
Manganese*	259.08	237.00	107.00	1,010.00	903.00	105	0	0
Manganese**	515.25	494.00	296.00	1,370.00	1,074.00	104	1	0
Potassium*	2,001.34	1,690.00	630.00	4,000.00	3,370.00	105	0	0
Potassium**	11,024.90	10,900.00	7,040.00	17,100.00	10,060.00	104	1	0
Sodium*	11,506.86	9,220.00	3,000.00	30,300.00	27,300.00	105	0	0
Sodium**	30,369.23	29,300.00	21,200.00	45,900.00	24,700.00	104	1	0
Vanadium*	39.40	41.40	16.10	63.90	47.80	105	0	0
Vanadium**	89.96	93.85	50.20	122.00	71.80	104	1	0
Priority Pollutant Metals								
Antimony*	4.47	0.37	0.20	110.00	109.80	39	66	0
Antimony**	6.78	1.00	0.30	356.00	355.70	85	20	0
Arsenic*	12.42	6.49	1.60	500.00	498.40	105	0	0
Arsenic**	14.61	7.77	1.90	555.00	553.10	104	1	0
Beryllium*	0.27	0.26	0.10	0.48	0.38	101	4	0
Beryllium**	1.02	0.96	0.60	1.40	0.80	104	1	0
Cadmium*	0.43	0.30	0.10	1.72	1.62	94	11	0
Cadmium**	0.76	0.80	0.11	2.00	1.89	75	30	0
Chromium*	30.17	29.20	11.30	79.40	68.10	105	0	0
Chromium**	72.77	72.30	36.70	203.00	166.30	104	1	0
Copper*	41.95	30.00	4.00	330.00	326.00	105	0	0

Appendix D. Table 3. Continued.

COMPOUND (unit of measure)	MEAN	MEDIAN	MINIMUM	MAXIMUM	RANGE	N	NO. OF NON-DETECTED VALUES	NO. OF MISSING VALUES
Copper**	43.87	31.55	4.90	290.00	285.10	104	1	0
Lead*	34.80	21.80	2.64	500.00	497.36	105	0	0
Lead**	34.56	21.00	6.60	388.00	381.40	104	1	0
Mercury	0.24	0.13	0.01	1.50	1.49	105	0	0
Nickel*	25.61	27.60	11.00	41.70	30.70	105	0	0
Nickel**	36.21	37.00	17.00	55.00	38.00	104	1	0
Selenium*	0.61	0.58	0.31	0.96	0.65	52	53	0
Selenium**	0.61	0.56	0.31	1.10	0.79	64	41	0
Silver*	0.53	0.39	0.10	2.01	1.91	93	12	0
Silver**	1.48	1.45	1.20	1.80	0.60	4	101	0
Thallium*	0.25	0.20	0.11	1.79	1.68	100	5	0
Thallium**	0.32	0.31	0.21	0.62	0.41	58	47	0
Zinc*	82.56	63.90	19.10	1,290.00	1,270.90	105	0	0
Zinc**	108.11	91.20	29.60	1,450.00	1,420.40	104	1	0
*Titanium**	715.31	689.00	279.00	1,160.00	881.00	105	0	0
*Titanium***	3,286.92	3,420.00	1,670.00	5,090.00	3,420.00	104	1	0
Major Elements								
Silicon**	276,285.71	272,000.00	224,000.00	334,000.00	110,000.00	105	0	0
Trace Elements								
Tin*						0	0	105
Tin**	8.81	4.03	0.75	166.00	165.25	104	1	0

* strong acid digestion
** hydrofluoric acid digestion
Italics - compound not from original project list

Appendix D. Table 3. Continued.

COMPOUND (unit of measure)	MEAN	MEDIAN	MINIMUM	MAXIMUM	RANGE	N	NO. OF NON-DETECTED VALUES	NO. OF MISSING VALUES
Organotins (ug/kg dry wt)								
Dibutyltin Dichloride	28.46	15.00	0.74	170.00	169.26	67	38	0
Tetrabutyltin	108.74	17.15	0.49	3,110.00	3,109.51	86	19	0
Monobutyltin						0	0	105
Tributyltin Chloride	108.74	17.15	0.49	3,110.00	3,109.51	86	19	0
ORGANICS (ug/kg dry wt)								
Chlorinated Aromatic Compounds								
1,2,4-trichlorobenzene	3.58	3.58	0.77	6.40	5.63	2	103	0
1,2-dichlorobenzene	2.11	1.30	0.35	6.40	6.05	5	100	0
1,3-dichlorobenzene	6.54	1.80	0.83	17.00	16.17	3	102	0
1,4-dichlorobenzene	8.62	3.60	0.34	79.00	78.66	40	65	0
2-chloronaphthalene						0	1	104
Hexachlorobenzene	0.62	0.34	0.10	4.50	4.40	29	76	0
Chlorinated Alkanes								
Hexachlorobutadien						0	105	0
Chlorinated and Nitro-Substituted Phenols								
Pentachlorophenol	194.22	159.00	98.00	527.00	429.00	23	82	0
HPAHs								
Benzo(a)anthracene	200.67	72.00	1.50	1760.00	1758.50	105	0	0
Benzo(a)pyrene	298.56	99.00	1.30	2910.00	2908.70	105	0	0
Benzo(b)fluoranthene	452.08	157.00	2.60	6670.00	6667.40	105	0	0
Benzo(e)pyrene	183.64	78.50	1.50	1280.00	1278.50	104	0	0
Benzo(g,h,i)perylene	158.50	83.00	1.40	1000.00	998.60	105	0	0
Benzo(k)fluoranthene	181.15	59.00	0.59	2360.00	2359.41	104	0	0
Chrysene	260.53	118.00	2.60	1710.00	1707.40	105	0	0
Dibenzo(a,h)anthracene	34.43	17.00	0.48	392.00	391.52	102	3	0
Fluoranthene	868.13	182.00	4.90	43000.00	42995.10	105	0	0
Indeno(1,2,3-c,d)pyrene	163.18	86.00	1.20	1220.00	1218.80	105	0	0
Perylene	135.63	104.00	4.20	949.00	944.80	105	0	0
Pyrene	621.47	206.00	4.50	14400.00	14395.50	105	0	0
C1-Chrysenes	43.08	16.00	0.12	778.00	777.88	75	30	0
C1-Fluoranthene/Pyrene	130.76	59.00	1.30	1160.00	1158.70	103	2	0

Appendix D. Table 3. Continued.

COMPOUND (unit of measure)	MEAN	MEDIAN	MINIMUM	MAXIMUM	RANGE	N	NO. OF NON-DETECTED VALUES	NO. OF MISSING VALUES
C2-Chrysenes	14.37	6.95	0.27	134.00	133.73	20	85	0
C3-Chrysenes	7.73	3.80	0.21	50.00	49.79	31	74	0
C4-Chrysenes						0	105	0
LPAHs								
1,6,7-Trimethylnaphthalene	21.72	17.00	0.99	136.00	135.01	102	3	0
1-Methylnaphthalene	29.33	17.00	0.92	728.00	727.08	99	6	0
1-Methylphenanthrene	35.90	27.00	1.20	195.00	193.80	100	5	0
2,6-Dimethylnaphthalene	47.80	37.00	1.10	272.00	270.90	103	2	0
2-Methylnaphthalene	50.54	29.00	1.40	1030.00	1028.60	99	6	0
2-Methylphenanthrene	51.76	38.00	2.20	312.00	309.80	102	3	0
Acenaphthene	52.36	7.30	0.48	1670.00	1669.52	93	12	0
Acenaphthylene	30.94	15.00	0.05	193.00	192.95	104	1	0
Anthracene	131.33	32.00	0.97	1120.00	1119.03	105	0	0
Biphenyl	19.85	9.00	0.44	387.00	386.56	94	11	0
Dibenzothiophene	23.58	9.20	1.00	334.00	333.00	89	16	0
Fluorene	54.77	17.00	0.76	830.00	829.24	102	3	0
Naphthalene	195.69	38.00	1.90	8370.00	8368.10	96	9	0
Phenanthrene	280.98	93.50	3.30	3830.00	3826.70	102	3	0
Retene	85.56	46.00	1.90	1320.00	1318.10	103	2	0
C1-Dibenzothiophenes	1.21	0.89	0.02	3.30	3.29	28	77	0
C1-Fluorenes	1.72	0.88	0.08	17.00	16.92	50	55	0
C1-Naphthalenes	80.94	44.00	1.80	1950.00	1948.20	101	4	0
C1-Phenanthrenes/Anthracenes	194.35	126.00	4.60	1170.00	1165.40	99	6	0
C2 -Naphthalenes	101.52	86.00	2.20	1040.00	1037.80	103	2	0
C2-Dibenzothiophenes	2.33	1.65	0.72	7.70	6.98	14	91	0
C2-Fluorenes	0.98	0.98	0.98	0.98	0.00	1	104	0
C2-Phenanthrenes/Anthracenes	67.12	43.50	0.08	406.00	405.92	44	61	0
C3 -Naphthalenes	101.23	87.00	3.40	627.00	623.60	105	0	0
C3-Dibenzothiophenes	6.41	4.45	0.20	44.00	43.80	42	63	0
C3-Fluorenes	2.50	2.50	0.98	4.40	3.42	5	100	0
C3-Phenanthrenes/Anthracenes	23.31	18.00	0.32	114.00	113.68	102	3	0
C4 -Naphthalenes	0.98	0.98	0.98	0.98	0.00	1	104	0
C4-Phenanthrenes/Anthracenes	75.11	45.00	1.90	706.00	704.10	103	2	0

Appendix D. Table 3. Continued.

COMPOUND (unit of measure)	MEAN	MEDIAN	MINIMUM	MAXIMUM	RANGE	N	NO. OF NON-DETECTED VALUES	NO. OF MISSING VALUES
Miscellaneous Extractable Compounds								
Benzoic acid	3,159.32	2,290.00	607.00	13,000.00	12,393.00	95	10	0
Benzyl alcohol	38.58	34.00	21.00	75.00	54.00	26	79	0
Dibenzofuran	59.40	14.00	1.10	2,010.00	2,008.90	99	6	0
Organonitrogen Compounds								
N-nitrosodiphenylamine	19.54	14.00	5.70	34.00	28.30	5	100	0
Phenols								
2,4-dimethylphenol	13.13	12.00	4.30	35.00	30.70	19	86	0
2-methylphenol	7.76	6.40	1.20	48.00	46.80	67	38	0
4-methylphenol	642.50	31.00	2.20	6,250.00	6,247.80	97	8	0
Phenol	201.73	109.00	44.00	1,730.00	1,686.00	40	65	0
P-nonylphenol	19.50	19.50	18.00	21.00	3.00	2	103	0
Phthalate Esters								
Bis(2-ethylhexyl)phthalate	512.19	460.00	139.00	1,030.00	891.00	16	89	0
Butyl benzyl phthalte	50.14	47.00	7.70	92.00	84.30	20	85	0
Diethyl phthalate	40.50	25.00	3.50	151.00	147.50	21	84	0
Dimethyl phthalate	19.27	11.10	3.30	65.00	61.70	12	93	0
Di-n-butyl phthalate	557.33	364.00	70.00	2,890.00	2,820.00	30	75	0
Di-n-octyl phthalate	16.00	16.00	16.00	16.00	0.00	1	104	0
Chlorinated Pesticides								
Aldrin						0	105	0
Alpha-chlordane	1.00	1.00	0.59	1.40	0.81	2	103	0
Alpha-HCH (Alpha BHC)						0	105	0
Beta-HCH (Beta BHC)						0	105	0
Delta-HCH (Delta BHC)						0	105	0
Dieldrin						0	105	0
Endo-sulfansulfate						0	105	0
Endrin						0	105	0
Endrin ketone						0	105	0
Endrin-aldehyde						0	105	0
Gamma-chlordane (Trans-Chlordane)	2.41	2.41	0.71	4.10	3.39	2	103	0

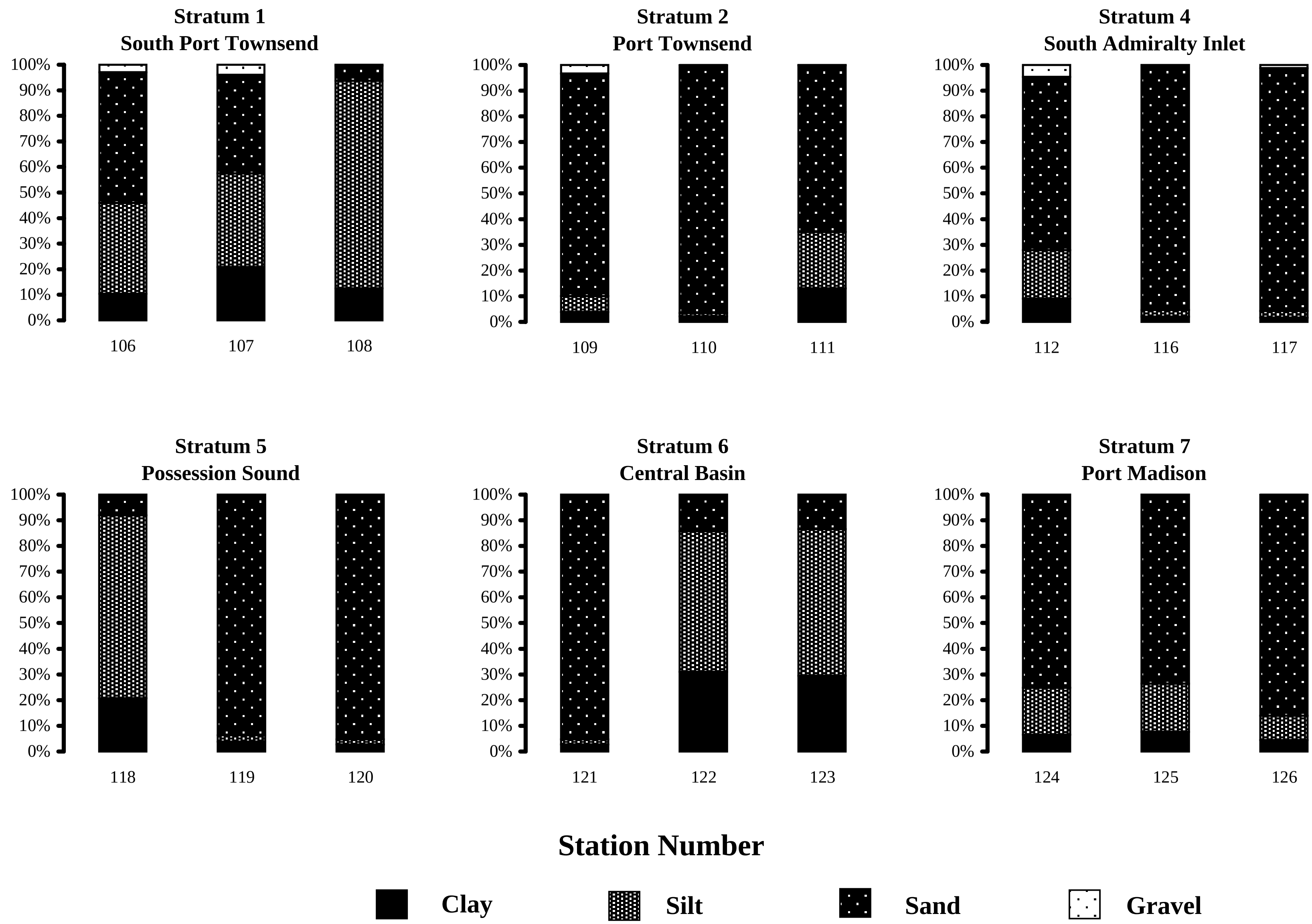
Appendix D. Table 3. Continued.

COMPOUND (unit of measure)	MEAN	MEDIAN	MINIMUM	MAXIMUM	RANGE	N	NO. OF NON-DETECTED VALUES	NO. OF MISSING VALUES
Gamma-HCH (Gamma BHC) (Lindane	1.34	1.34	0.57	2.10	1.53	2	103	0
Heptachlor						0	105	0
Heptachlor epoxide						0	105	0
Methoxychlor	10.00	10.00	10.00	10.00	0.00	1	104	0
2,4'-DDD						0	105	0
4,4'-DDD	4.07	3.15	0.80	14.00	13.20	36	69	0
2,4'-DDE						0	105	0
4,4'-DDE	3.00	2.20	0.21	12.00	11.79	44	61	0
2,4'-DDT						0	105	0
4,4'-DDT	3.73	3.45	3.00	5.00	2.00	4	101	0
Cis-nonachlor						0	105	0
Trans-nonachlor	0.58	0.58	0.58	0.58	0.00	1	104	0
Oxychlordane						0	105	0
Mirex						0	105	0
Endosulfan I (Alpha-endosulfan)						0	105	0
Endosulfan II (Beta-endosulfan)						0	105	0
Chlorpyrifos						0	105	0
Toxaphene						0	105	0
Polycyclic Chlorinated Biphenyls								
PCB Arochlors:								
1016						0	105	0
1221						0	105	0
1232						0	105	0
1242	19.44	12.00	4.20	50.00	45.80	7	98	0
1248						0	105	0
1254	53.06	30.50	2.50	300.00	297.50	54	51	0
1260	108.77	39.00	2.70	2,000.00	1,997.30	63	42	0
1268						0	23	0
PCB Congeners:								
8	0.73	0.62	0.25	1.70	1.45	7	98	0
18	1.36	0.84	0.21	6.80	6.59	33	72	0
28	2.79	1.30	0.09	24.00	23.91	47	58	0
44	1.52	0.98	0.24	8.80	8.56	52	53	0
52	2.73	1.50	0.12	22.00	21.88	63	42	0

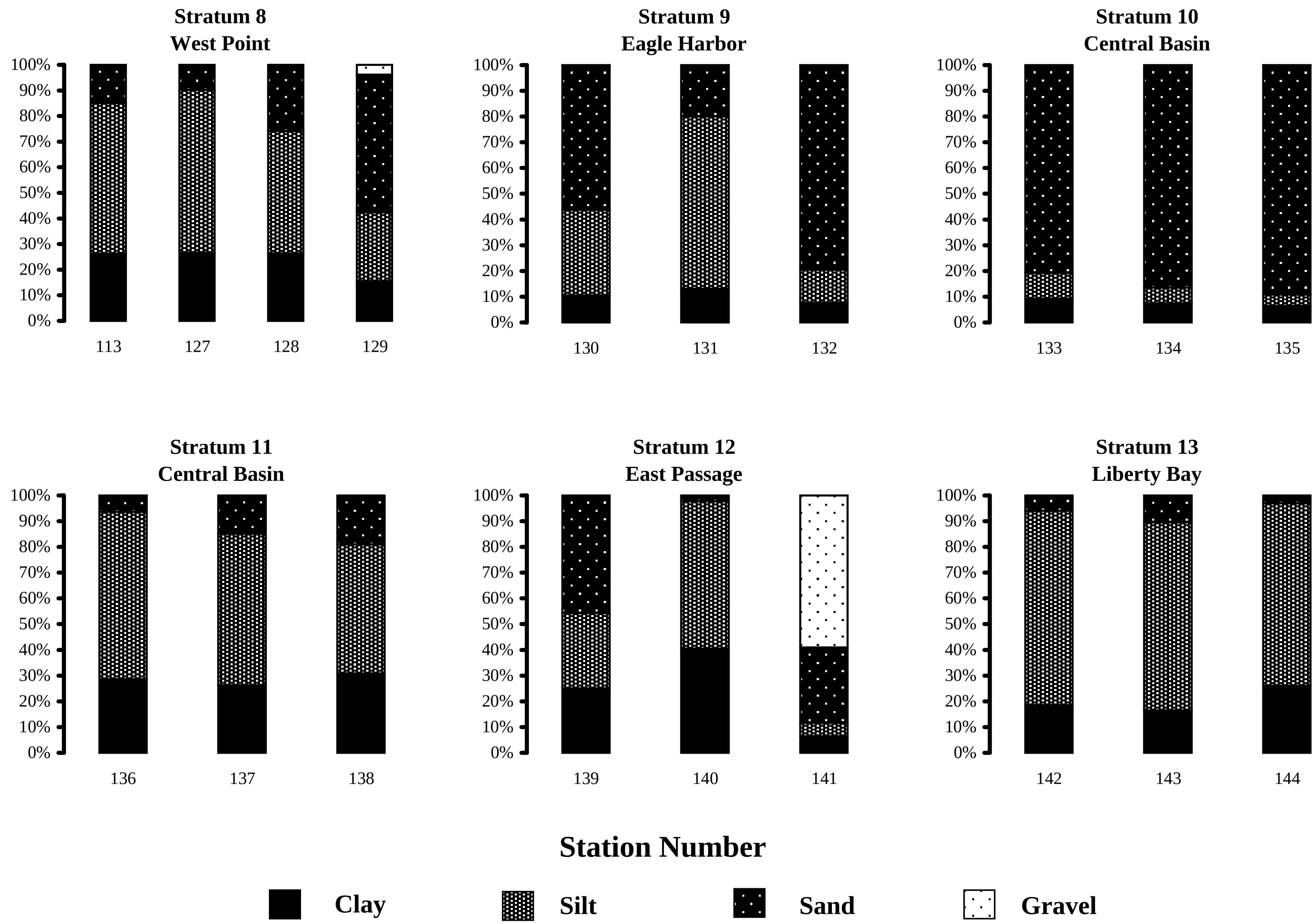
Appendix D. Table 3. Continued.

COMPOUND (unit of measure)	MEAN	MEDIAN	MINIMUM	MAXIMUM	RANGE	N	NO. OF NON-DETECTED VALUES	NO. OF MISSING VALUES
66	2.20	1.20	0.10	24.00	23.90	63	42	0
77	7.50	7.50	7.50	7.50	0.00	1	104	0
101	6.22	2.40	0.07	76.00	75.93	71	34	0
105	4.11	2.20	0.13	35.00	34.87	59	46	0
118	3.94	2.55	0.10	29.00	28.90	72	33	0
126	1.40	1.40	1.40	1.40	0.00	1	104	0
128	2.13	1.10	0.07	14.00	13.93	61	44	0
138	10.05	4.60	0.23	140.00	139.77	65	40	0
153	9.25	2.90	0.11	210.00	209.89	79	26	0
170	5.63	1.90	0.07	110.00	109.93	63	42	0
180	8.68	2.60	0.11	190.00	189.89	65	40	0
187	6.37	2.60	0.18	100.00	99.82	52	53	0
195	1.57	0.61	0.12	18.00	17.88	37	68	0
206	1.45	0.80	0.08	8.70	8.62	56	49	0

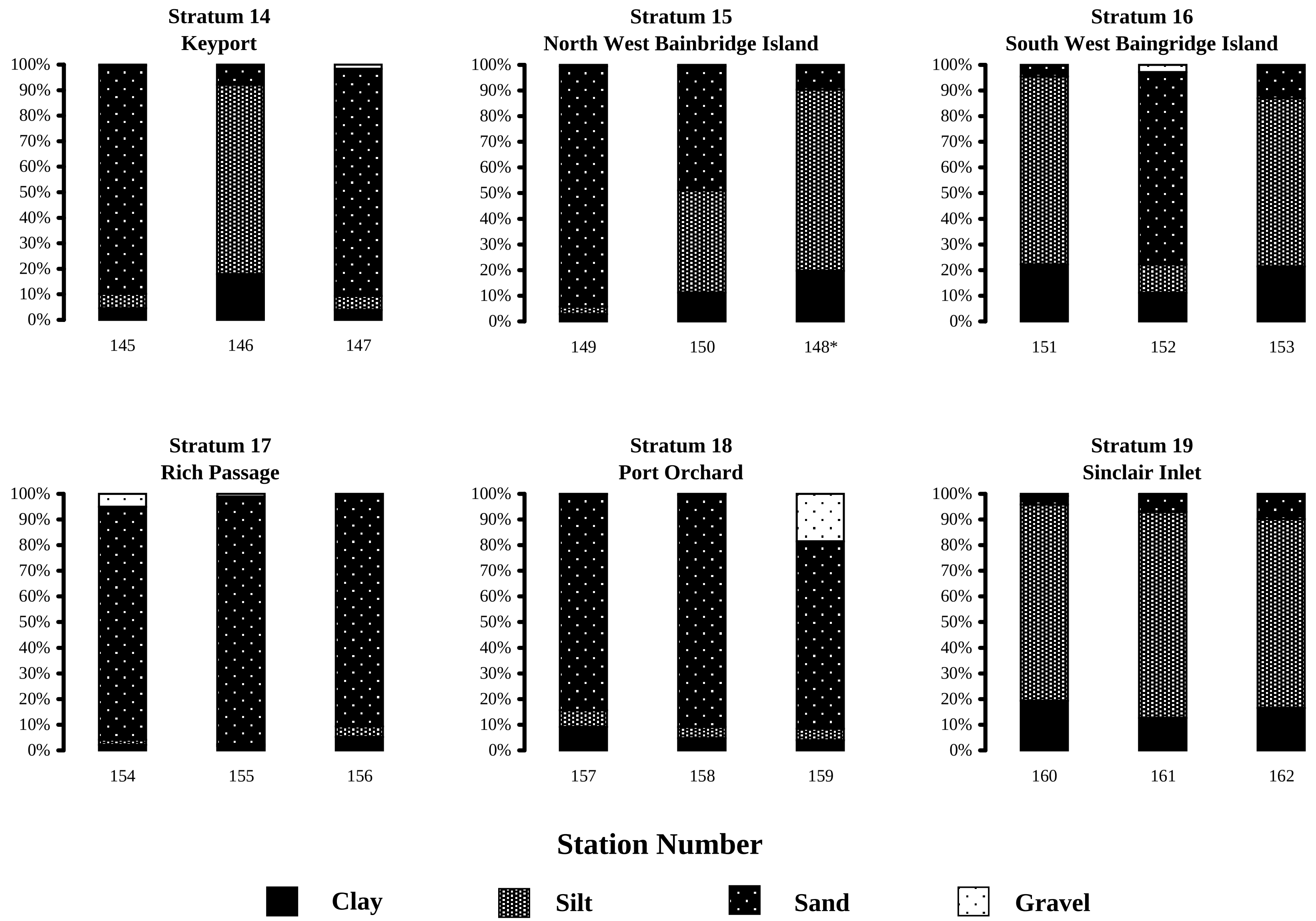
Appendix D, Figure 1. Grain size distribution for the 1998 central Puget Sound sampling stations (grain size in fractional percent).



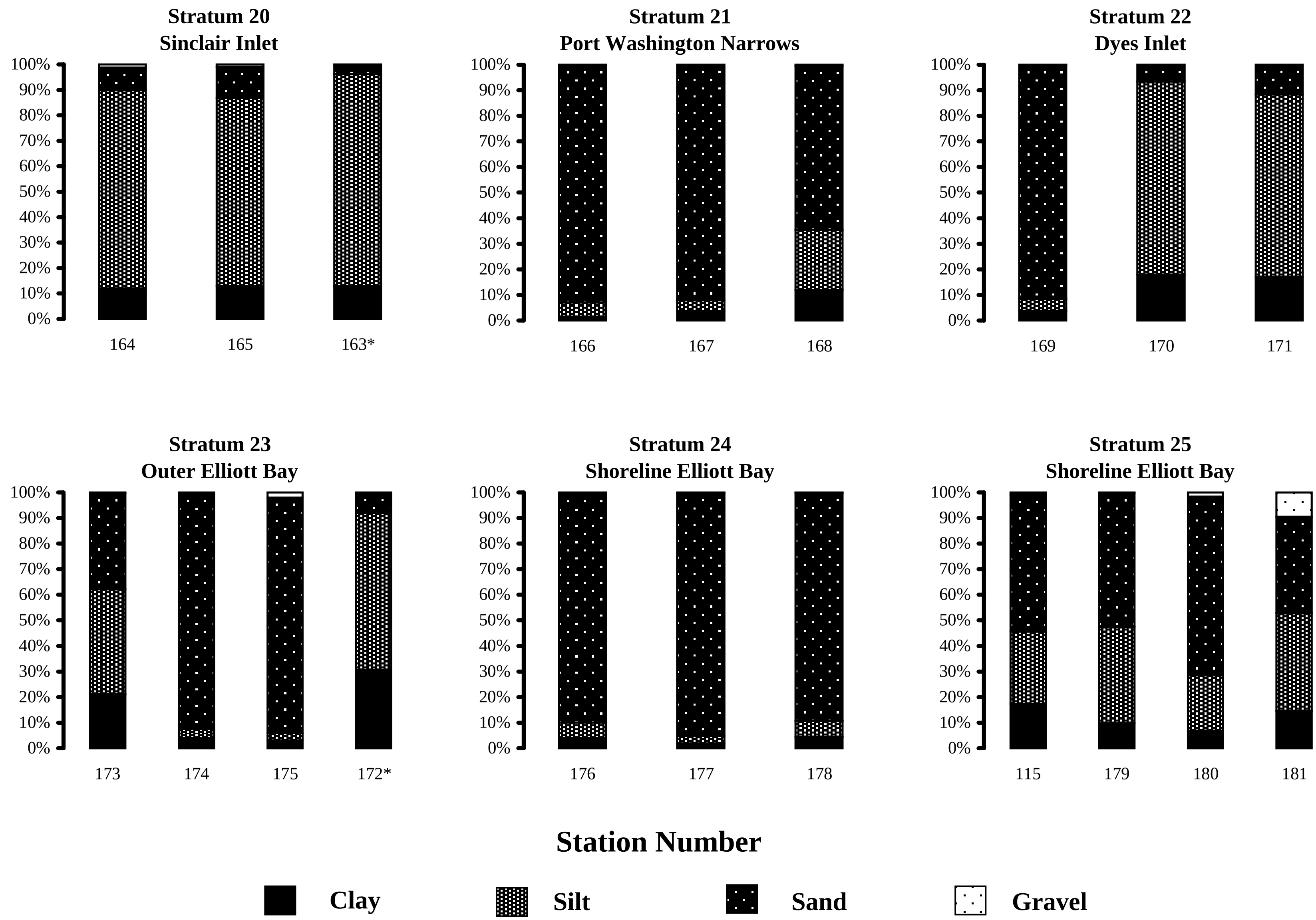
Appendix D, Figure 1. continued.



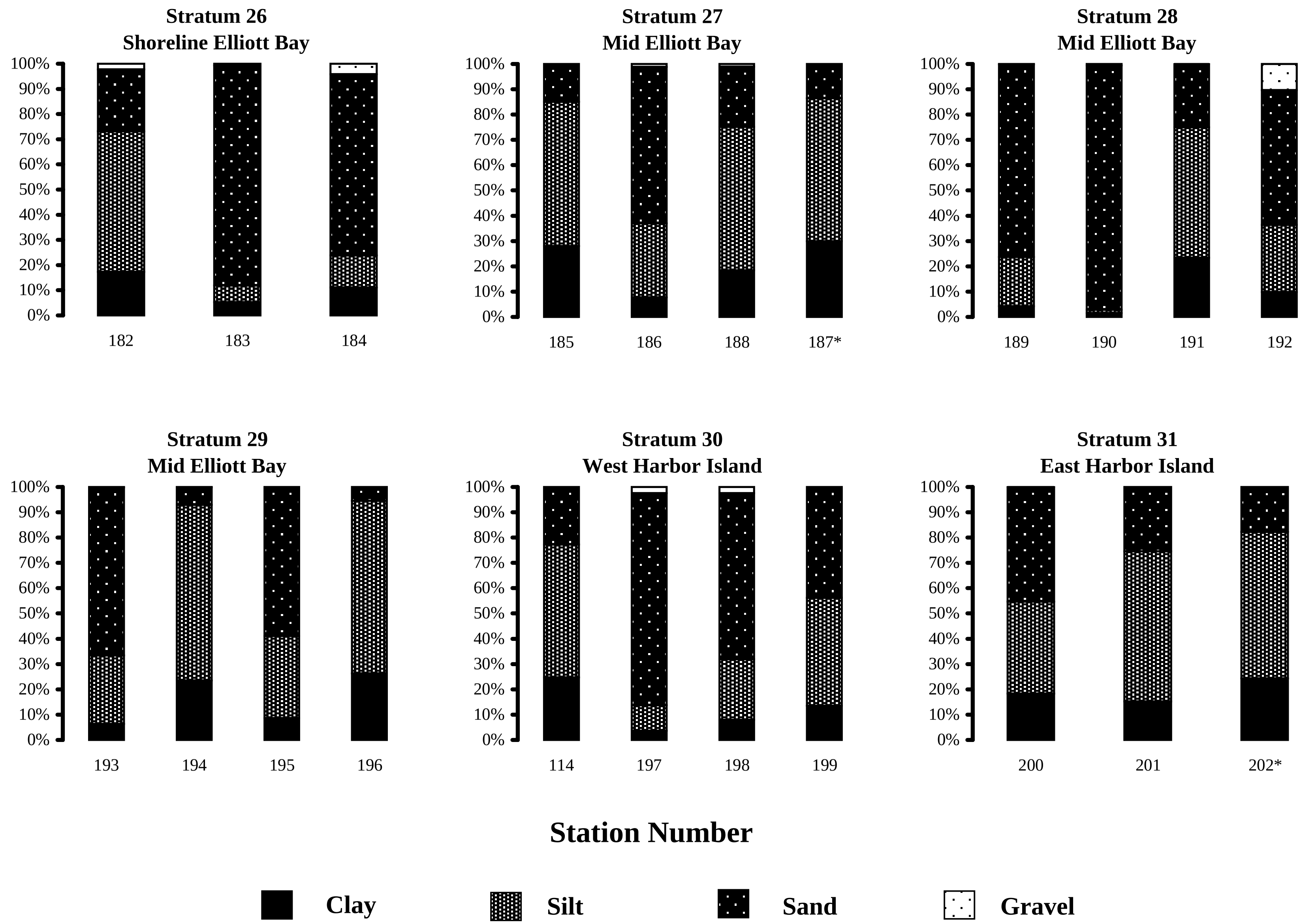
Appendix D, Figure 1. continued.



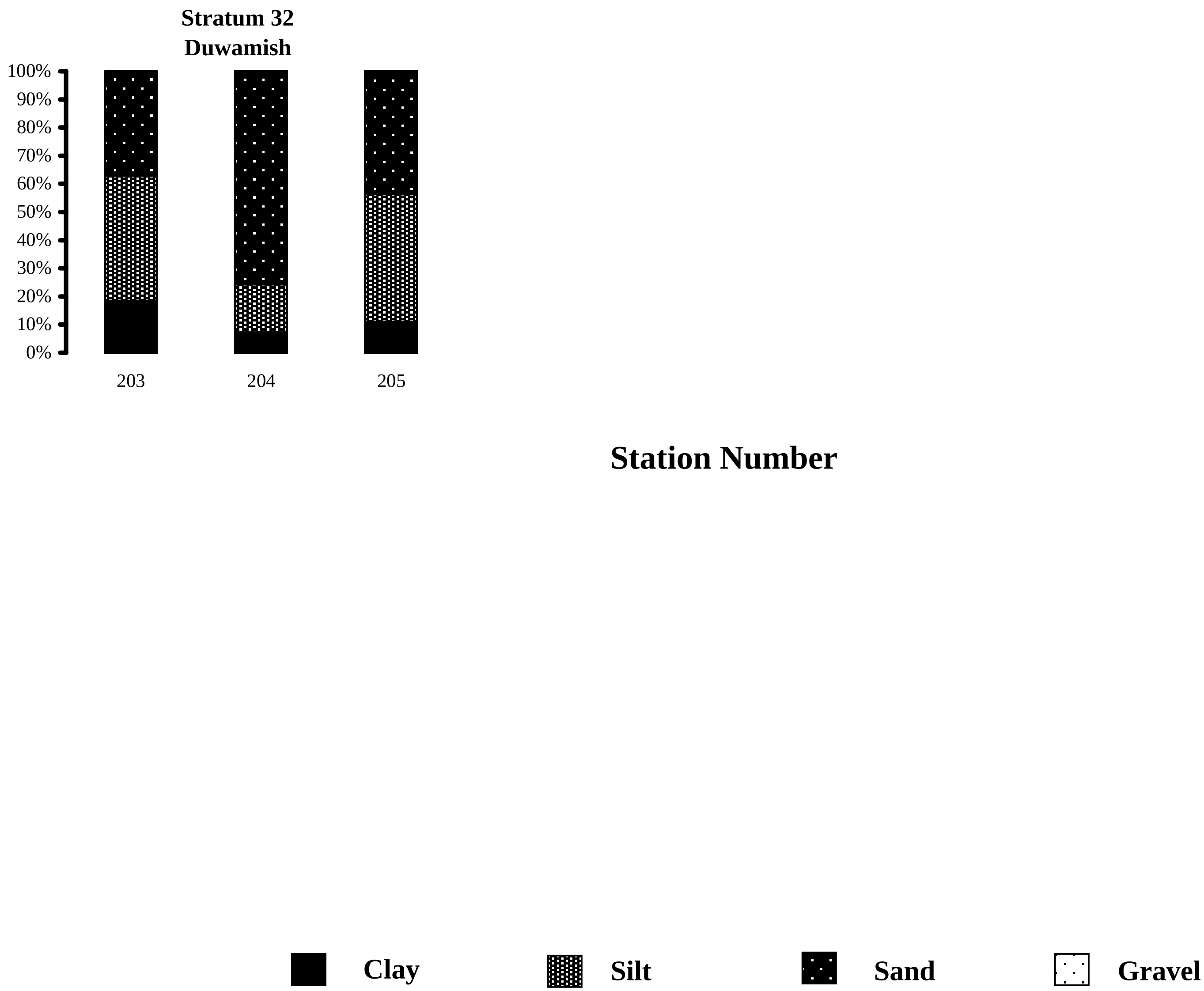
Appendix D, Figure 1. continued.



Appendix D, Figure 1. continued.



Appendix D, Figure 1. continued.



Appendix E

1998 Central Puget Sound benthic infaunal species list.

Appendix E. 1998 Central Puget Sound benthic infaunal species list.

Phylum	Class	Family	Taxon	Author
Porifera	Calcerea	Grantiidae	*Leucandra sp.*	
	Demospongiae		*Demospongiae*	
		Myxillidae	*Myxilla incrustans*	(Esper 1805-1814)
Cnidaria	Hydrozoa	Bougainvilliidae	*Perigonimus sp.*	
		Tubulariidae	*Tubulariidae*	
		Corymorphidae	*Euphysa sp.*	
		Eudendriidae	*Eudendriidae*	
		Pandeidae	*Pandeidae*	
		Campanulariidae	*Campanulariidae*	
			Clytia sp.	
		Sertulariidae	*Abietinaria sp.*	
		Calycellidae	*Calycella sp.*	
	Anthozoa	Cerianthidae	*Cerianthidae*	
			Pachycerianthus sp.	
			Pachycerianthus fimbriatus	Mcmurrich 1910
		Virgulariidae	*Stylatula elongata*	(Gabb 1862)
		Pennatulidae	*Ptilosarcus gurneyi*	(Gray 1860)
		Edwardsiidae	*Edwardsia sipunculoides*	(Stimpson 1853)
		Halcampidae	*Halcampa sp.*	
			Halcampa decemtentaculata	Hand 1954
	Anthozoa		*Peachia quinquecapitata*	Mcmurrich, 1913
		Metridiidae	*Metridium sp.*	
Platyhel-minthes			*Polycladida*	
	Turbellaria	Stylochidae	*Stylochidae*	
		Leptoplanidae	*Leptoplanidae*	
			Kalyptorhynchia	
Nemertina	Anopla		*Paleonemertea*	
		Tubulanidae	*Tubulanus sp.*	
			Tubulanus capistratus	(Coe 1901)
			Tubulanus polymorphus	Renier 1804
			Tubulanus pellucidus	
			Tubulanus sp. A	
			Tubulanus sp. B	
		Carinomidae	*Carinoma mutabilis*	Griffin 1898
		Lineidae	*Lineidae*	
			Cerebratulus sp.	
			Lineus sp.	
			Micrura sp.	
	Enopla		*Hoplonemertea*	
			Monostylifera	
		Emplectonematidae	*Paranemertes californica*	Coe 1904

Appendix E. Continued.

Phylum	Class	Family	Taxon	Author
		Prosorhochmidae	*Oerstedia dorsalis*	(Abildgaard 1806)
		Amphiporidae	*Amphiporus sp.*	
			Zygonemertes virescens	
		Tetrastemmatidae	*Tetrastemma sp.*	
			Tetrastemma nigrifrons	Coe 1904
Nematoda			*Nematoda*	
Annelida	Polychaeta	Aphroditidae	*Aphrodita sp.*	
			Aphrodita negligens	Moore 1905
		Polynoidae	*Polynoidae*	Malmgren, 1867
			Bylgides macrolepidus	
			Arcteobia cf. anticostiensis	SCAMIT 1990 §
			Arctonoe vittata	(Grube, 1855)
			Eunoe sp.	
			Eunoe uniseriata	
			Gattyana ciliata	Moore, 1902
			Gattyana cirrosa	(Malmgren, 1865)
			Gattyana treadwelli	Pettibone, 1949
			Harmothoe sp.	
			Harmothoe extenuata	
			Harmothoe imbricata	(Linnaeus 1767)
			Harmothoe multisetosa	(Moore 1902)
			Harmothoe fragilis	Moore 1910
			Harmothoinae	
			Lepidonotus sp.	
			Lepidonotus spiculus	(Treadwell 1906)
			Hesperonoe sp.	
			Lepidasthenia sp.	
			Lepidasthenia berkeleyae	Pettibone 1948
			Lepidasthenia longicirrata	E. Berkeley 1923
			Tenonia priops	(Hartman 1961)
			Malmgreniella nigralba	(E. Berkeley 1923)
			Malmgreniella scriptoria	(Moore 1910)
			Malmgreniella bansei	Pettibone 1993
		Pholoidae	*Pholoides aspera*	
			Pholoe minuta	(Fabricius)
			Pholoe sp. N1	
		Sigalionidae	*Sthenelais sp.*	
			Sthenelais berkeleyi	Pettibone 1971
			Sthenelais tertiaglabra	Moore 1910
			Sthenelais fusca	Johnson 1897
		Chrysopetalidae	*Paleanotus bellis*	(Johnson 1897)
		Phyllodocidae	*Phyllodoce (Anaitides) citrina*	
			Eteone sp.	
			Eteone pacifica	
			Eteone spilotus	

Appendix E. Continued.

Phylum	Class	Family	Taxon	Author
			Eteone leptotes	Blake 1992
			Eulalia californiensis	(Hartman 1936)
			Eumida sp.	
			Eumida tubiformis	
			Eumida longicornuta	(Moore 1906)
			Phyllodoce sp.	
			Phyllodoce (Aponaitides) hartmanae	
			Phyllodoce (Anaitides) cuspidata	Mccammon & Montagne 1979
			Phyllodoce (Anaitides) groenlandica	
			Phyllodoce (Anaitides) longipes	
			Phyllodoce (Anaitides) mucosa	
			Phyllodoce (Anaitides) williamsi	
			Sige bifoliata	
			Pterocirrus macroceros	
		Hesionidae	*Microphthalmus sczelkowii*	
			Micropodarke dubia	(Hessle 1925)
			Heteropodarke heteromorpha	Hartmann-Schröder 1962
			Podarke pugettensis	Johnson 1901
			Podarkeopsis glabrus	
		Pilargidae	*Sigambra tentaculata*	(Treadwell 1941)
			Pilargis maculata	
			Parandalia fauveli	(Berkeley & Berkeley 1941)
		Syllidae	*Pionosyllis uraga*	Imajima 1966
			Syllis spongiphila	
			Syllis (Ehlersia) hyperioni	Dorsey & Phillips 1987
			Syllis (Ehlersia) heterochaeta	Moore 1909
			Syllis (Typosyllis) harti	
			Eusyllis blomstrandi	
			Eusyllis magnifica	
			Eusyllis habei	Imajima 1966
			Exogone (E.) lourei	
			Exogone (Parexogone) molesta	
			Exogone dwisula	Kudenov & Harris 1995
			Sphaerosyllis californiensis	Hartman 1966
			Sphaerosyllis ranunculus	Kudenov & Harris 1995

Appendix E. Continued.

Phylum	Class	Family	Taxon	Author
			Sphaerosyllis sp. N1	
			Odontosyllis phosphorea	Moore 1909
			Proceraea cornuta	
		Nereididae	*Nereididae*	
			Nereis procera	Ehlers 1868
			Nereis zonata	
			Platynereis bicanaliculata	(Baird, 1863)
		Nephtyidae	*Nephtys caeca*	(Fabricius)
			Nephtys cornuta	Berkeley & Berkeley 1945
			Nephtys punctata	Hartman 1938
			Nephtys ferruginea	Hartman 1940
			Nephtys caecoides	Hartman 1938
		Sphaerodoridae	*Sphaerodoropsis sphaerulifer*	(Moore 1909)
		Glyceridae	*Glycera americana*	Leidy 1855
			Glycera nana	Johnson 1901
		Goniadidae	*Glycinde armigera*	Moore 1911
			Glycinde polygnatha	
			Goniada sp..	
			Goniada maculata	Ørsted 1843
			Goniada brunnea	Treadwell 1906
		Onuphidae	*Onuphidae*	
			Onuphis sp.	
			Onuphis geophiliformis	(Moore 1903)
			Onuphis iridescens	(Johnson 1901)
			Onuphis elegans	(Johnson 1901)
			Diopatra	
			Diopatra ornata	Moore 1911
		Lumbrineridae	*Lumbrineris sp.*	
			Eranno bicirrata	(Treadwell 1922)
			Lumbrineris latreilli	Audouin & H. Milne Edwards 1834
			Scoletoma luti	
			Lumbrineris cruzensis	Hartman 1944
			Lumbrineris californiensis	Hartman 1944
			Ninoe gemmea	
		Oenonidae	*Drilonereis longa*	Webster
			Notocirrus californiensis	Hartman 1944
		Dorvilleidae	*Dorvillea (D.) sp.*	
			Dorvillea (Schistomeringos) rudolphi	
			Dorvillea (Schistomeringos) annulata	(Moore 1906)
			Protodorvillea gracilis	(Hartman 1938)
			Parougia caeca	(Webster & Benedict 1884)

Appendix E. Continued.

Phylum	Class	Family	Taxon	Author
		Orbiniidae	*Orbiniidae*	Hartman, 1942
			Leitoscoloplos pugettensis	(Pettibone 1957)
			Scoloplos nr. yamaguchii	
			Naineris quadricuspida	(Fabricius)
			Naineris uncinata	Hartman 1957
			Scoloplos sp.	
			Scoloplos armiger	(Muller)
			Scoloplos acmeceps	Chamberlin 1919
			Phylo felix	Kinberg 1866
		Paraonidae	*Aricidea cf. pseudoarticulata*	
			Aricidea sp.	
			Aricidea (Acmira) catherinae	Laubier 1967
			Aricidea (Acmira) lopezi	Berkeley & Berkeley 1956
			Aricidea (Allia) ramosa	
			Levinsenia gracilis	(Tauber 1879)
			Paradoneis sp.	
		Apistobranchidae	*Apistobranchus ornatus*	Hartman 1965
		Spionidae	*Spionidae*	
			Laonice cirrata	(M. Sars 1851)
			Laonice pugettensis	
			Polydora sp.	
			Dipolydora socialis	(Schmarda 1861)
			Dipolydora caulleryi	(Mesnil 1897)
			Polydora limicola	Annenkova 1934
			Dipolydora cardalia	
			Dipolydora quadrilobata	
			Dipolydora nr. akaina	
			Dipolydora armata	
			Prionospio sp.	
			Prionospio steenstrupi	Malmgren
			Prionospio (Minuspio) lighti	Maciolek 1985
			Prionospio jubata	
			Prionospio (Minuspio) multibranchiata	E. Berkeley 1927
			Spio filicornis	(O. F. Müller 1766)
			Spio cirrifera	
			Boccardia pugettensis	Blake 1979
			Spiophanes bombyx	(Claparède 1870)
			Spiophanes berkeleyorum	Pettibone 1962
			Pygospio elegans	
			Paraprionospio pinnata	(Ehlers 1901)
			Scolelepis squamata	(O. F. Müller 1806)
			Boccardiella hamata	(Webster 1879)
		Magelonidae	*Magelona sp.*	
			Magelona longicornis	Johnson 1901
			Magelona sacculata	Hartman 1961

Appendix E. Continued.

Phylum	Class	Family	Taxon	Author
			Magelona berkeleyi	Jones 1971
		Trochochaetidae	*Trochochaeta multisetosa*	(Ørsted 1844)
		Chaetopteridae	*Chaetopterus variopedatus*	(Renier, 1804)
			Phyllochaetopterus prolifica	Potts 1914
			Spiochaetopterus costarum	(Claparède 1870)
			Mesochaetopterus taylori	
		Cirratulidae	*Cirratulidae*	
			Cirratulus sp.	
			Cirratulus robustus	
			Cirratulus spectabilis	
			Caulleriella pacifica	
			Aphelochaeta sp.	
			Aphelochaeta monilaris	(Hartman 1960)
			Aphelochaeta sp. 2	
			Aphelochaeta sp. N1	
			Chaetozone sp.	
			Chaetozone nr. setosa	
			Chaetozone columbiana	Blake 1996
			Chaetozone commonalis	
			Chaetozone acuta	
			Chaetozone sp. N1	
			Tharyx sp. N1	
			Monticellina tesselata	(Hartman 1960)
			Monticellina sp. N1	
			Monticellina sp.	
			Cossura pygodactylata	Jones 1956
			Cossura bansei	
		Flabelligeridae	*Brada villosa*	(Rathke 1843)
			Brada sachalina	Annenkova,1922
			Flabelligera affinis	
			Pherusa plumosa	
		Scalibregmidae	*Scalibregma inflatum*	Rathke 1843
			Asclerocheilus beringianus	
		Opheliidae	*Armandia brevis*	(Moore 1906)
			Travisia brevis	Moore 1923
			Travisia pupa	Moore 1906
			Ophelina acuminata	Ørsted 1843
		Sternaspidae	*Sternaspis scutata*	
		Capitellidae	*Capitella capitata hyperspecies*	
			Heteromastus filobranchus	Berkeley & Berkeley 1932
			Notomastus sp.	
			Notomastus tenuis	Moore 1909
			Notomastus latericeus	M. Sars 1851
			Mediomastus sp.	
			Decamastus gracilis	Hartman 1963

Appendix E. Continued.

Phylum	Class	Family	Taxon	Author
			Barantolla nr. americana	
		Maldanidae	*Maldanidae sp.*	
			Chirimia similis	
			Maldane sarsi	Malmgren 1865
			Nicomache lumbricalis	(Fabricius 1780)
			Nicomache personata	Johnson 1901
			Notoproctus pacificus	(Moore 1906)
			Petaloproctus borealis	Arwidsson 1907
			Axiothella rubrocincta	(Johnson 1901)
			Praxillella gracilis	(M. Sars 1861)
			Praxillella pacifica	E. Berkeley 1929
			Euclymeninae	
			Rhodine bitorquata	Moore 1923
			Euclymene cf. zonalis	
			Clymenura gracilis	Hartman 1969
			Microclymene caudata	
			Nicomachinae	
			Isocirrus longiceps	(Moore 1923)
		Oweniidae	*Owenia fusiformis*	Delle Chiaje 1841
			Myriochele heeri	
			Galathowenia oculata	
		Sabellariidae	*Idanthyrsus saxicavus*	
			Neosabellaria cementarium	(Moore 1906)
		Pectinaridae	*Pectinaria granulata*	
			Pectinaria californiensis	Hartman 1941
		Ampharetidae	*Ampharetidae*	
			Amage anops	(Johnson 1901)
			Ampharete sp.	
			Ampharete acutifrons	(Grube 1860)
			Ampharete finmarchica	
			Ampharete labrops	Hartman 1961
			Ampharete cf. crassiseta	
			Amphicteis scaphobranchiata	Moore 1906
			Amphicteis mucronata	Moore 1923
			Melinna oculata	Hartman 1969
			Anobothrus gracilis	(Malmgren 1866)
			Asabellides sibirica	
			Asabellides lineata	(Berkeley & Berkeley 1943)
			Schistocomus hiltoni	Chamberlin 1919
		Terebellidae	*Terebellidae*	
			Amphitrite robusta	Johnson 1901
			Eupolymnia heterobranchia	(Johnson 1901)
			Nicolea sp.	
			Nicolea zostericola	
			Pista sp.	
			Pista elongata	Moore 1909

Appendix E. Continued.

Phylum	Class	Family	Taxon	Author
			Pista brevibranchiata	
			Pista estevanica	
			Pista wui	
			Pista bansei	
			Polycirrus sp.	
			Polycirrus californicus	Moore 1909
			Polycirrus sp. I (sensu Banse, 1980)	
			Thelepus sp.	
			Thelepus setosus	(Quatrefages 1865)
			Artacama coniferi	Moore 1905
			Lanassa nordenskioldi	
			Lanassa venusta	
			Proclea graffii	
			Scionella japonica	Moore 1903
			Streblosoma bairdi	
			Amphitrite edwardsi	
			Polycirrinae	
		Trichobranchidae	*Terebellides sp.*	
			Terebellides stroemi	
			Terebellides californica	Williams 1984
			Terebellides reishi	Williams 1984
			Terebellides nr. lineata	
			Artacamella hancocki	Hartman 1955
		Sabellidae	*Sabellidae*	
			Chone sp.	
			Chone duneri	
			Chone magna	
			Euchone incolor	Hartman 1965
			Euchone limnicola	Reish 1960
			Eudistylia sp.	
			Eudistylia polymorpha	
			Eudistylia vancouveri	(Kinberg 1867)
			Eudistylia catherinae	
			Megalomma splendida	(Moore 1905)
			Demonax sp.	
			Schizobranchia insignis	
			Bispira elegans	
			Laonome kroeyeri	
			Sabellinae	
			Demonax rugosus	(Moore, 1904)
		Saccocirridae	*Saccocirrus sp.*	
		Serpulidae	*Serpulidae*	
			Pseudochitinopoma occidentalis	Bush,1909
		Spirorbidae	*Circeis sp.*	
	Oligochaeta		*Oligochaeta*	

Appendix E. Continued.

Phylum	Class	Family	Taxon	Author
Mollusca	Gastropoda		*Gastropoda*	Cuvier,1797
		Fissurellidae	*Puncturella cooperi*	Carpenter 1864
		Trochidae	*Trochidae*	Rafinesque, 1815
			Calliostoma ligatum	(Gould, 1849)
			Solariella sp.	
			Lirularia lirulata	
		Lacunidae	*Lacuna vincta*	(Montagu, 1803)
		Rissoidae	*Alvania compacta*	Carpenter, 1864
		Cerithiidae	*Lirobittium sp.*	
		Eulimidae	*Balcis oldroydae*	(Bartsch 1917)
		Trichotropididae	*Trichotropis cancellata*	Hinds, 1843
		Calyptraeidae	*Calyptraea fastigiata*	Gould 1856
			Crepipatella dorsata	(Broderip 1834)
		Naticidae	*Euspira pallida*	
		Nucellidae (Thaisidae)	*Nucella lamellosa*	(Gmelin,1791)
		Columbellidae	*Amphissa sp.*	
			Amphissa columbiana	Dall,1916
			Alia carinata	(Hinds 1844)
			Astyris gausapata	
		Nassariidae	*Nassarius mendicus*	(Gould 1849)
		Olividae	*Olivella baetica*	Carpenter 1864
			Olivella pycna	Berry 1935
		Turridae	*Kurtziella crebricostata*	
			Kurtzia arteaga	(Dall & Bartsch 1910)
			Ophiodermella cancellata	(Carpenter 1864)
		Pyramidellidae	*Odostomia sp.*	
			Turbonilla sp.	
		Cylichnidae	*Acteocina culcitella*	(Gould 1853)
			Cylichna attonsa	Carpenter 1865
			Scaphander sp.	
			Retusa sp.	
		Aglajidae	*Melanochlamys diomedea*	(Bergh 1893)
		Gastropteridae	*Gastropteron pacificum*	Bergh 1893
			Nudibranchia	Cuvier,1817
		Notodorididae	*Aegires albopunctatus*	Macfarland 1905
		Onchidorididae	*Onchidoris bilamellata*	(Linnaeus,1767)
		Flabellinidae	*Flabellina sp.*	
	Polyplacophora		*Polyplacophora*	
		Ischnochitonida	*Ischnochiton albus*	
			Lepidozona mertensii	(Middendorff 1847)
			Lepidozona interstincta	(Gould 1852)
		Mopaliidae	*Mopalia lignosa*	
	Aplacophora	Chaetodermatidae	*Chaetoderma sp.*	
	Bivalvia		*Bivalvia*	Linnaeus,1758
		Nuculidae	*Acila castrensis*	(Hinds 1843)

Appendix E. Continued.

Phylum	Class	Family	Taxon	Author
		Nuculanidae	*Ennucula tenuis*	
			Nuculana minuta	(Fabricius,1776)
			Nuculana cf. cellulita	
		Sareptidae	*Yoldia sp.*	
			Yoldia hyperborea	Torell,1859
			Yoldia seminuda	Dall 1871
			Yoldia thraciaeformis	
		Mytilidae	*Mytilidae*	
			Mytilus sp.	
			Solamen columbiana	
			Musculus discors	(Linnaeus,1767)
			Modiolus rectus	(Conrad 1837)
		Pectinidae	*Chlamys hastata*	(G. B. Sowerby Ii 1843)
		Anomiidae	*Pododesmus macroschisma*	(Deshayes,1839)
		Lucinidae	*Parvilucina tenuisculpta*	(Carpenter 1864)
			Lucinoma annulatum	(Reeve 1850)
		Thyasiridae	*Adontorhina cyclia*	Berry 1947
			Axinopsida serricata	(Carpenter 1864)
			Thyasira flexuosa	(Montagu 1803)
		Lasaeidae	*Lasaea adansoni*	(Gmelin 1791)
		Montacutidae	*Rochefortia tumida*	
		Lasaeidae	*Rochefortia cf. coani*	
		Carditidae	*Cyclocardia ventricosa*	(Gould 1850)
		Cardiidae	*Clinocardium sp.*	
			Clinocardium nuttallii	(Conrad 1837)
			Nemocardium centifilosum	(Carpenter 1864)
		Mactridae	*Mactromeris polynyma*	(Stimpson,1860)
		Solenidae	*Solen sicarius*	Gould 1850
		Tellinidae	*Macoma sp.*	
			Macoma elimata	Dunnill & Coon,1968
			Macoma obliqua	(Sowerby,1817)
			Macoma moesta	(Deshayes,1855)
			Macoma yoldiformis	Carpenter 1864
			Macoma carlottensis	Whiteaves 1880
			Macoma nasuta	(Conrad 1837)
			Macoma inquinata	(Deshayes,1855)
			Tellina sp.	
			Tellina nuculoides	(Reeve 1854)
			Tellina modesta	(Carpenter 1864)
		Semelidae	*Semele rubropicta*	Dall 1871
		Veneridae	*Saxidomus giganteus*	(Deshayes,1839)
			Compsomyax subdiaphana	(Carpenter 1864)
			Protothaca staminea	(Conrad 1837)
			Nutricola lordi	(Baird 1863)
			Nutricola tantilla	(Gould 1853)

Appendix E. Continued.

Phylum	Class	Family	Taxon	Author
		Myidae	*Mya arenaria*	Linnaeus 1758
		Hiatellidae	*Hiatella arctica*	(Linnaeus 1767)
			Panomya sp.	
			Panopea abrupta	(Conrad 1849)
		Pandoridae	*Pandora filosa*	(Carpenter 1864)
		Lyonsiidae	*Lyonsia californica*	Conrad 1837
		Thraciidae	*Thracia sp.*	
			Thracia trapezoides	Conrad 1849
			Poromya sp.	
		Cuspidariidae	*Cardiomya pectinata*	(Carpenter 1864)
	Scaphopoda	Pulsellidae	*Pulsellum salishorum*	E. Marshall,1980
Arthropoda	Pycnogonida	Nymphonidae	*Nymphon heterodenticulatum*	Hedgpeth 1941
		Phoxichilidiidae	*Phoxichilidium sp.*	
			Phoxichilidium femoratum	
			Anoplodactylus viridintestinalis	
	Ostracoda	Cylindroleberididae	*Bathyleberis sp.*	
		Rutidermatidae	*Rutiderma lomae*	(Juday 1907)
		Philomedidae	*Euphilomedes carcharodonta*	(Smith 1952)
			Euphilomedes producta	Poulsen 1962
			Philomedida sp. A	
	Copepoda	Calanoida	*Calanoida*	Mauchline, 1988
		Harpacticoida	Harpacticoida	
			Orthopsyllus linearis	
		Ascidocolidae	*Ascidocolidae*	
		Caligidae	*Caligidae*	Kabata, 1988
		Argulidae	*Argulidae*	
	Cirripedia	Balanidae	*Balanus sp.*	
			Balanus glandula	
			Balanus nubilus	Darwin 1854
	Malacostraca	Nebaliidae	*Nebalia pugettensis*	
			Mysidacea	
		Mysidae	*Pacifacanthomysis nephrophthalma*	(Banner 1948)
			Heteromysis odontops	Walker 1898
			Neomysis kadiakensis	Ortmann 1908
			Pseudomma berkeleyi	W. Tattersall 1932
			Pseudomma sp. A	
			Alienacanthomysis sp.	
		Lampropidae	*Lamprops quadriplicata*	
			Lamprops serrata	
			Lamprops sp. A	
		Leuconiidae	*Leucon nasica*	
			Eudorella (tridentata) pacifica	
			Eudorellopsis cf. integra	
			Eudorellopsis integra	

Appendix E. Continued.

Phylum	Class	Family	Taxon	Author
			Eudorellopsis longirostris	Given 1961
			Nippoleucon hinumensis	
		Diastylidae	*Diastylis paraspinulosa*	
			Diastylis santamariensis	Watling & Mccann 1997
			Diastylopsis dawsoni	
			Leptostylis cf. villosa	
		Nannastacidae	*Campylaspis rufa*	Hart 1930
			Campylaspis canaliculata	Zimmer 1936
			Campylaspis hartae	Lie 1969
			Cumella vulgaris	
		Paratanaidae	*Leptochelia savignyi*	
		Anthuridae	*Haliophasma geminata*	Menzies And Barnard, 1959
		Aegidae	*Rocinela cf. propodialis*	
		Munnidae	*Munna sp.*	
		Munnopsidae	*Munnopsurus sp.*	
			Baeonectes improvisus	Wilson, 1982
		Paramunnidae	*Munnogonium tillerae*	(Menzies & J. L. Barnard 1959)
		Mysidae	*Iphimedia cf. ridkettsi*	
		Ampeliscidae	*Ampelisca sp.*	
			Ampelisca cristata	Holmes, 1908
			Ampelisca hancocki	J. L. Barnard, 1954
			Ampelisca pugetica	Stimpson 1864
			Ampelisca brevisimulata	J. L. Barnard 1954
			Ampelisca unsocalae	J. L. Barnard 1960
			Ampelisca lobata	Holmes 1908
			Ampelisca careyi	Dickinson 1982
			Ampelisca sp. A	
			Byblis millsi	Dickinson 1983
		Ampithoidae	*Ampithoe lacertosa*	Bate, 1858
		Aoridae	*Aoroides columbiae*	Walker 1898
			Aoroides inermis	Conlan & Bousfield 1982
			Aoroides intermedius	Conlan And Bousfield, 1982
			Aoroides sp.	
		Argissidae	*Argissa hamatipes*	(Norman 1869)
		Corophiidae	*Corophium (Monocorophium) acherusicum*	Costa, 1857
			Corophium salmonis	Stimpson, 1857
			Corophium (Monocorophium) insidiosum	
			Corophium cf. baconi	
			Corophium (Americorophium) spinicorne	

Appendix E. Continued.

Phylum	Class	Family	Taxon	Author
		Ischyroceridae	*Erichthonius rubricornis*	
		Aoridae	*Grandidierella japonica*	Stephensen 1938
		Dexaminidae	*Guernea reduncans*	(J. L. Barnard 1958)
		Pontogeneiidae	*Accedomoera vagor*	J. L. Barnard, 1969
		Eusiridae	*Eusirus sp.*	
			Eusirus columbianus	
			Pontogeneia rostrata	Gurjanova 1938
			Rhachotropis sp.	
			Rhachotropis barnardi	
		Melitidae	*Melitidae*	
			Anisogammarus pugettensis	Dana, 1853
			Desdimelita desdichada	(J. L. Barnard 1962)
		Isaeidae	*Photis sp.*	
			Photis brevipes	Shoemaker 1942
			Photis bifurcata	J. L. Barnard 1962
			Protomedeia sp.	
			Protomedeia grandimana	Bruggen, 1906
			Protomedeia prudens	J. L. Barnard 1966
			Gammaropsis sp.	
			Gammaropsis thompsoni	(Walker 1898)
			Gammaropsis ellisi	
			Cheirimedeia sp.	
			Cheirimedeia cf. macrocarpa	
			Cheirimedeia zotea	
		Ischyroceridae	*Ischyrocerus sp.*	
			Jassa marmorata	Lincoln, 1979
			Microjassa sp.	
		Oedicerotidae	*Americhelidium sp.*	
			Americhelidium rectipalmum	
			Americhelidium variabilum	
			Americhelidium pectinatum	
		Lysianassidae	*Aruga sp. A*	
			Orchomene cf. pinguis	
			Acidostoma sp.	
			Anonyx cf. lilljeborgi	
			Cyphocaris challengeri	Stebbing, 1888
			Hippomedon coecus	Holmes, 1908
			Lepidepecreum gurjanovae	Hurley 1963
			Opisa tridentata	Hurley 1963
			Orchomene pacifica	
			Orchomene decipiens	(Hurley 1963)
			Pachynus barnardi	Hurley, 1963
		Melphidippidae	*Melphidippa cf. borealis*	
			Melphidippa sp. A	
			Melphisana cf. bola	
		Oedicerotidae	*Oedicerotidae*	
			Aceroides sp.	

Appendix E. Continued.

Phylum	Class	Family	Taxon	Author
			Bathymedon pumilus	J. L. Barnard 1962
			Westwoodilla caecula	Bate, 1856
			Westwoodilla cf. caecula	(Bate 1857)
			Westwoodilla acutifrons	
			Deflexilodes sp.	
			Deflexilodes similis	
			Americhelidium variabilum	
		Pardaliscidae	*Pardalisca sp.*	
			Pardalisca cf. tenuipes	
			Rhynohalicella halona	
		Phoxocephalidae	*Harpiniopsis fulgens*	J. L. Barnard 1960
			Heterophoxus sp.	
			Heterophoxus oculatus	(Holmes 1908)
			Heterophoxus ellisi	Jarrett & Bousfield 1994
			Heterophoxus conlanae	
			Heterophoxus affinis	(Holmes 1908)
			Metaphoxus frequens	J. L. Barnard 1960
			Paraphoxus sp.	
			Paraphoxus similis	
			Rhepoxynius sp.	
			Rhepoxynius bicuspidatus	(J. L. Barnard 1960)
			Rhepoxynius cf. abronius	
			Rhepoxynius daboius	(J. L. Barnard 1960)
			Rhepoxynius boreovariatus	
			Foxiphalus similis	(J. L. Barnard 1960)
		Pleustidae	*Eochelidium sp.*	(J. L. Barnard & Given 1960)
			Gnathopleustes pugettensis	
			Hardametopa sp.	
			Incisocalliope sp.	(Alderman 1936)
			Parapleustinae	
			Pleusymtes coquilla	
			Pleusymtes sp. A	
			Pleusymtes subglaber	
			Thorlaksonius depressus	
			Tracypleustes sp.	
		Podoceridae	*Dulichia rhabdoplastis*	Mccloskey, 1970
			Podocerus cf. cristatus	(Thomson 1879)
			Dyopedos sp.	
			Dyopedos arcticus	Murdoch, 1885
		Stenothoidae	*Stenula modosa*	J. L. Barnard 1962
			Metopa sp.	
		Synopiidae	*Tiron biocellata*	J. L. Barnard 1962
		Hyperiidae	*Parathemisto pacifica*	
			Themisto pacifica	
		Aeginellidae	*Deutella californica*	Mayer 1890

Appendix E. Continued.

Phylum	Class	Family	Taxon	Author
			Mayerella banksia	Laubitz 1970
			Tritella pilimana	Mayer 1890
		Caprellidae	*Caprella sp.*	
			Caprella mendax	Mayer 1903
			Caprellidea	
			Metacaprella anomala	
		Hippolytidae	*Hippolytidae*	Bate, 1888
		Alpheidae	*Spirontocaris ochotensis*	(Brandt, 1851)
			Eualus subtilis	
			Heptacarpus stimpsoni	Holthuis 1947
		Pandalidae	*Pandalus sp.*	
		Cangonidae	*Crangon sp.*	
		Crangonidae	*Crangon sp.*	
			Crangon alaskensis	Lockington 1877
			Mesocrangon munitella	(Walker 1898)
		Axiidae	*Acanthaxius (Axiopsis) spinulicauda*	
		Callianassidae	*Neotrypaea gigas*	
			Neotrypaea californiensis	(Dana 1854)
		Paguridae	*Pagurus sp.*	
			Pagurus setosus	(Benedict, 1892)
			Discorsopagurus schmitti	(Stevens, 1925)
		Upogebiidae	*Upogebia sp.*	
		Majidae	*Majidae*	
			Oregonia gracilis	Dana, 1851
		Cancridae	*Cancer sp.*	
			Cancer gracilis	Dana 1852
			Cancer oregonensis	(Dana 1852)
		Xanthidae	*Lophopanopeus bellus*	(Stimpson 1860)
		Pinnotheridae	*Pinnixa sp.*	
			Pinnixa occidentalis	Rathbun 1893
			Pinnixa schmitti	Rathbun 1918
			Pinnixa tubicola	Holmes 1894
	Insecta		*Collembola*	
Sipuncula	Sipunculidea	Golfingiidae	*Thysanocardia nigra*	(Ikeda 1904)
			Thysanoessa cf. longipes	
			Nephasoma diaphanes	(Gerould 1913)
Echiura	Echiurida	Bonelliidae	*Bonelliidae*	
		Thalassematidae	*Arhynchite pugettensis*	
		Echiridae	*Echiurus echiurus alaskanus*	
Phorona		Phoronidae	*Phoronopsis harmeri*	
Bryozoa	Gymnolaemata	Alcyonidiidae	*Alcyonidium sp.*	
			Nolella sp.	

Appendix E. Continued.

Phylum	Class	Family	Taxon	Author
		Vesiculariidae	*Bowerbankia gracilis*	Leidy 1855
		Alderinidae	*Copidozoum tenuirostre*	
		Bugulidae	*Bugula sp.*	
		Bicellariellidae	*Dendrobeania lichenoides*	
		Bugulidae	*Caulibugula sp.*	
		Hippothoidae	*Hippothoa hyalina*	(Linnaeus, 1767)
		Smittinidae	*Smittina sp.*	
		Celleporidae	*Celleporina robertsoniae*	
		Chapperiellidae	*Chapperiella sp.*	
	Stenolaemata	Crisiidae	*Crisia sp.*	
		Tubuliporidae	*Tubulipora sp.*	
Entoprocta		Barentsiidae	*Barentsia sp.*	
			Barentsia benedeni	(Foettinger 1887)
		Pedicellinidae	*Myosoma spinosa*	
Brachiopoda	Articulata	Cancellothyrididae	*Terebratulina sp.*	
		Laqueidae	*Terebratalia transversa*	(G. B. Sowerby I 1846)
			Terebratulida	
Echinodermata	Asteroidea		Asteroidea	
		Goniasteridae	*Mediaster aequalis*	Stimpson 1857
		Solasteridae	*Crossaster papposus*	(Linnaeus, 1767)
			Solaster stimpsoni	Verrill, 1880
	Ophiuroidea		*Ophiurida*	Muller & Troschel, 1940
		Ophiuridae	*Ophiura lutkeni*	(Lyman, 1860)
	Ophiuroidea	Amphiuridae	*Amphiuridae*	Ljungman, 1867
			Amphiodia sp.	
			Amphiodia urtica/periercta complex	
			Amphipholis squamata	(Delle Chiaje 1828)
	Echinoidea	Strongylocentrotidae	*Strongylocentrotus sp.*	
		Dendrasteridae	*Dendraster excentricus*	(Eschscholtz 1831)
	Holothuroidea		*Dendrochirotida*	Brandt, 1835
		Sclerodactylidae	*Eupentacta sp.*	
		Cucumariidae	*Cucumariidae*	Ludwig, 1894
			Cucumaria piperata	(Stimpson 1864)
		Phyllophoridae	*Pentamera sp.*	
			Pentamera populifera	(Stimpson 1857)
			Pentamera pseudocalcigera	Deichmann 1938
			Pentamera pseudopopulifera	Deichmann 1938
		Cucumariidae	*Pseudocnus sp.*	
		Synaptidae	*Leptosynapta sp.*	
		Mopadiidae	*Molpadia intermedia*	(Ludwig 1894)

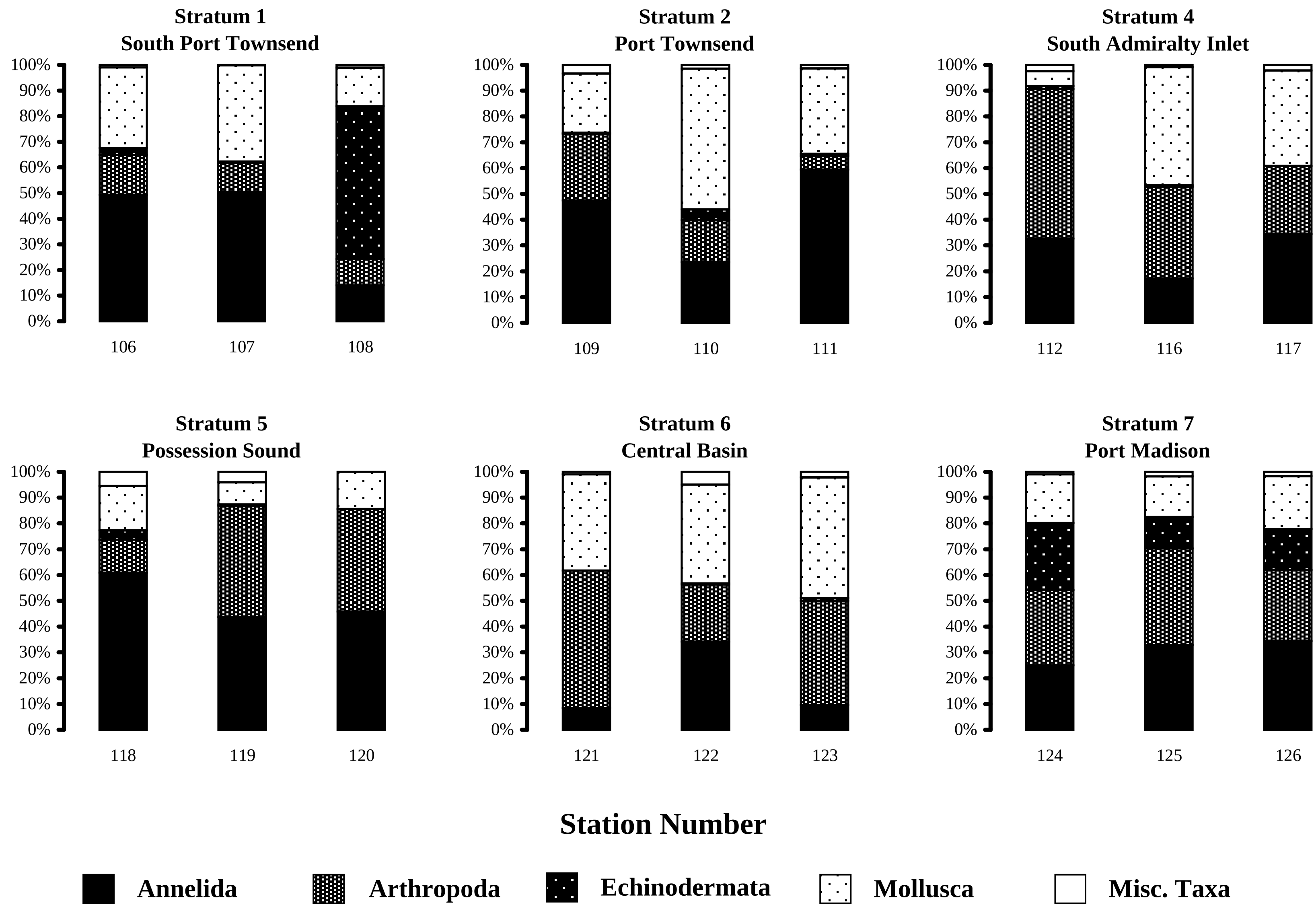
Appendix E. Continued.

Phylum	Class	Family	Taxon	Author
Hemichordata	Enteropneusta		Enteropneusta	
Chordata	Ascidiacea	Clavelinidae	*Distaplia sp.*	
			Phlebobranchia	Lahille
		Corellidae	*Corella willmeriana*	Herdman 1898
			Stolidobranchia	Lahille
		Styelidae	*Styela sp.*	
			Styela gibbsii	(Stimpson 1864)
		Pyuridae	*Boltenia villosa*	(Stimpson 1864)
		Molgulidae	*Molgula pugetiensis*	Herdman 1898
			Eugyra arenosa	Alder & Hancock,1848

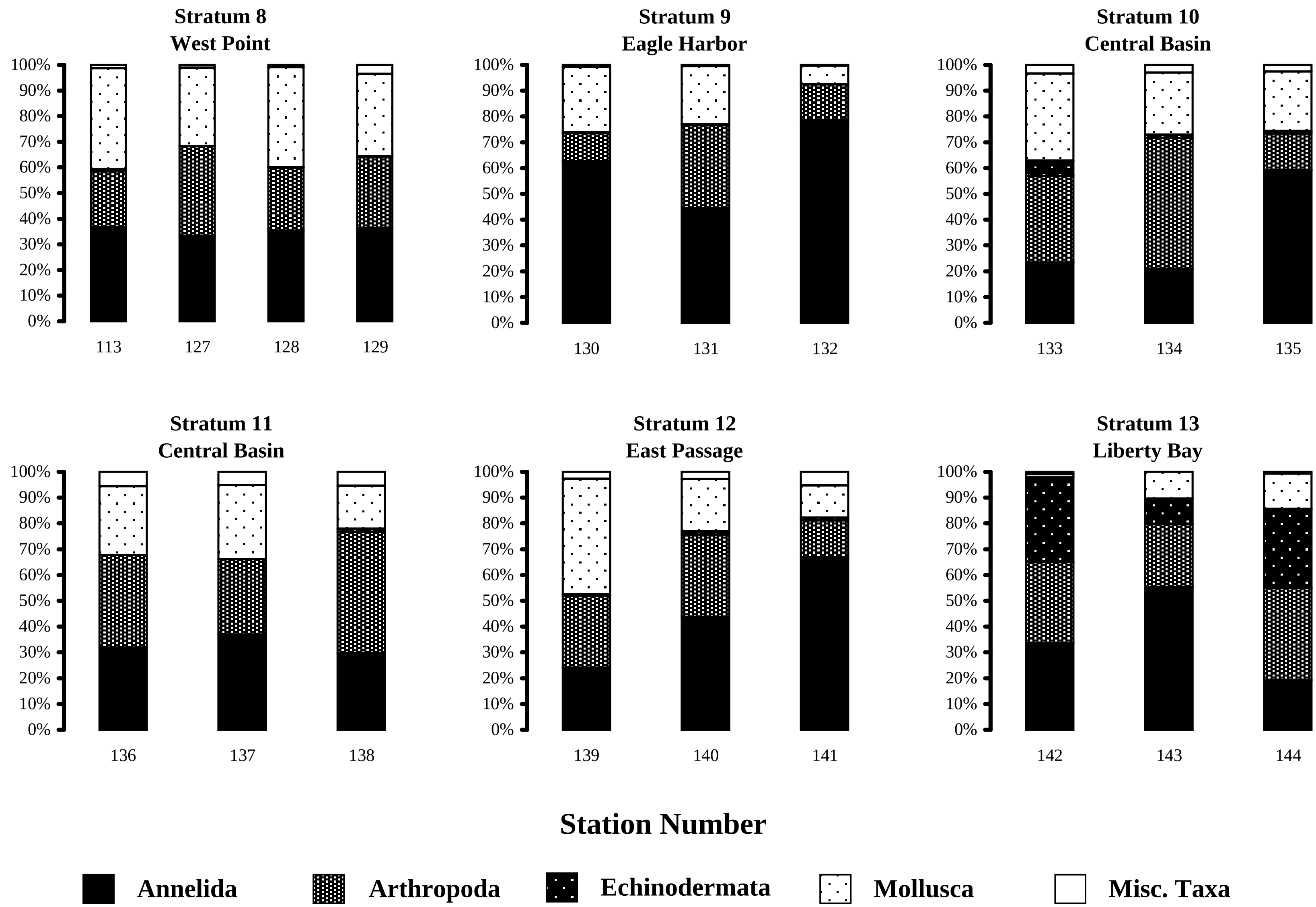
Appendix F

Percent taxa abundance for the 1998 central Puget Sound sampling stations.

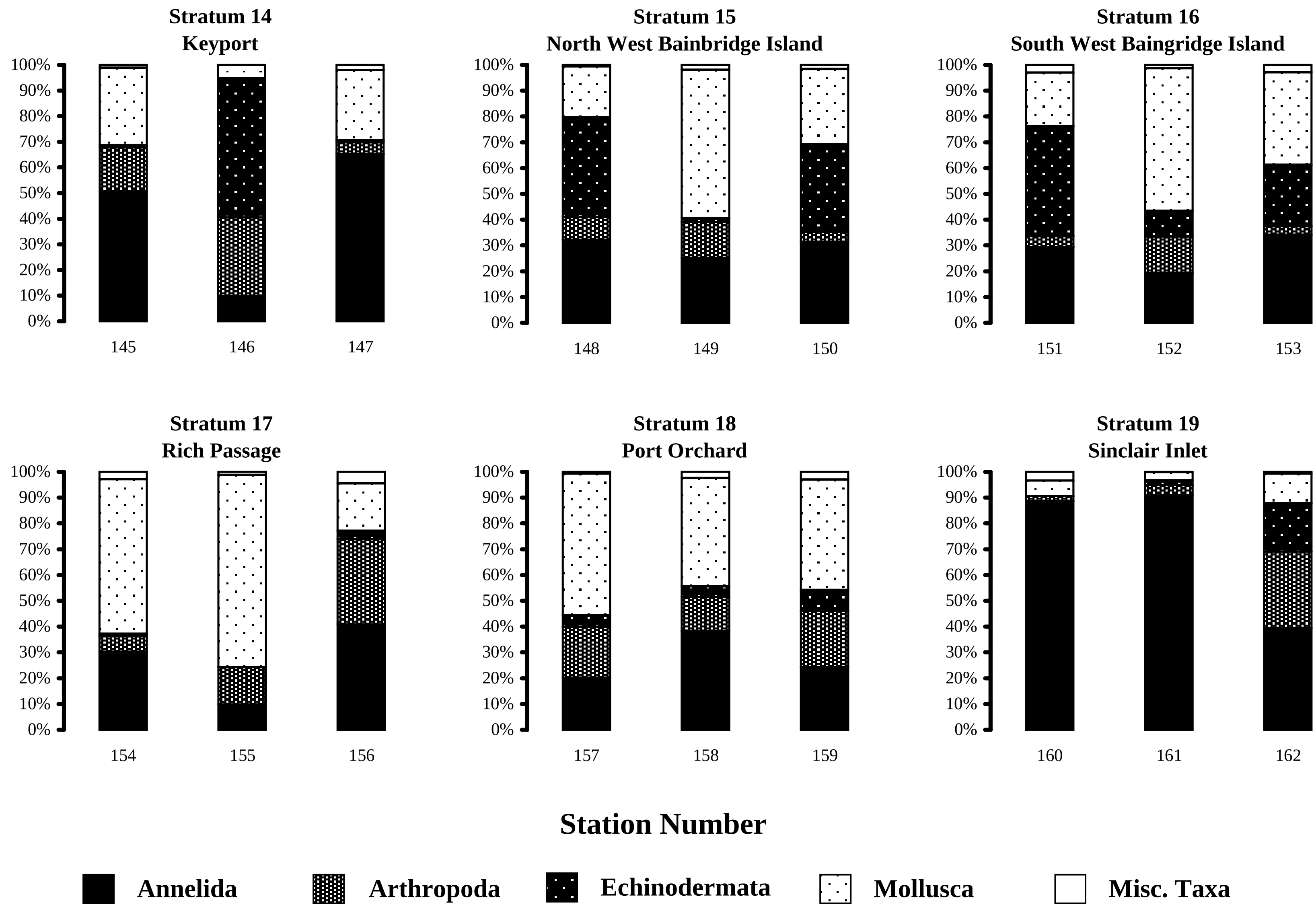
Appendix F. Percent taxa abundance for the 1998 central Puget Sound sampling stations.



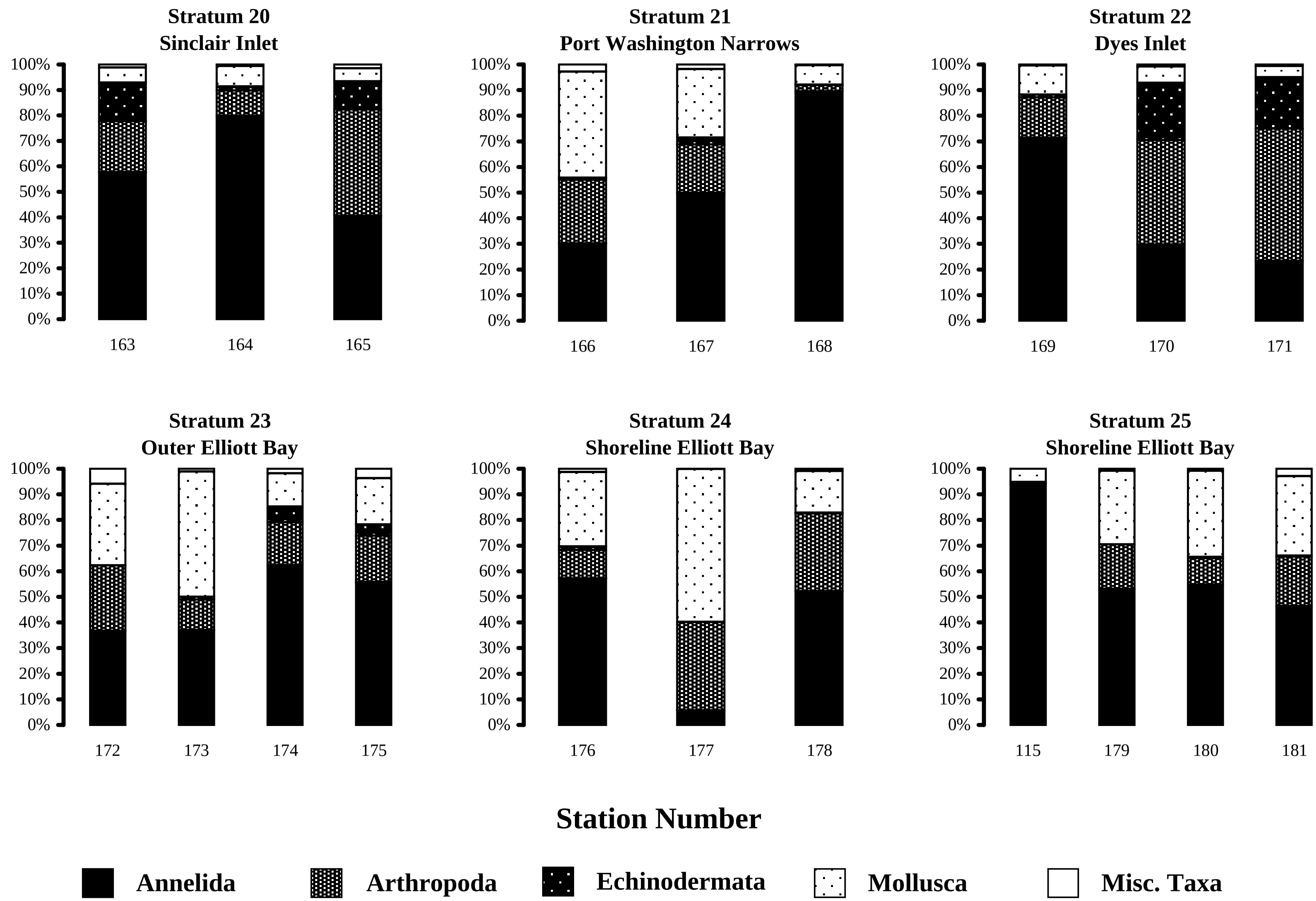
Appendix F. continued.



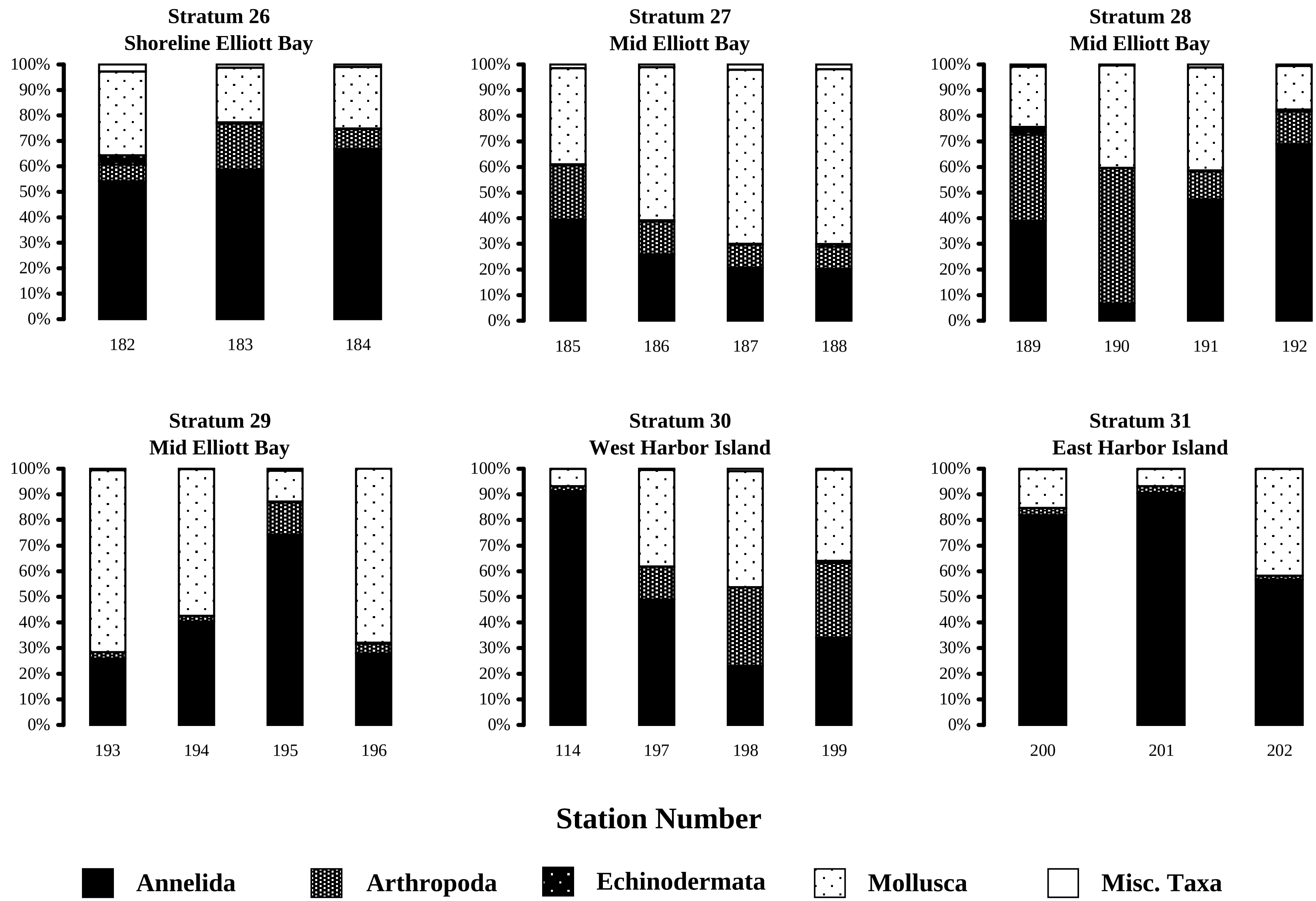
Appendix F. continued.



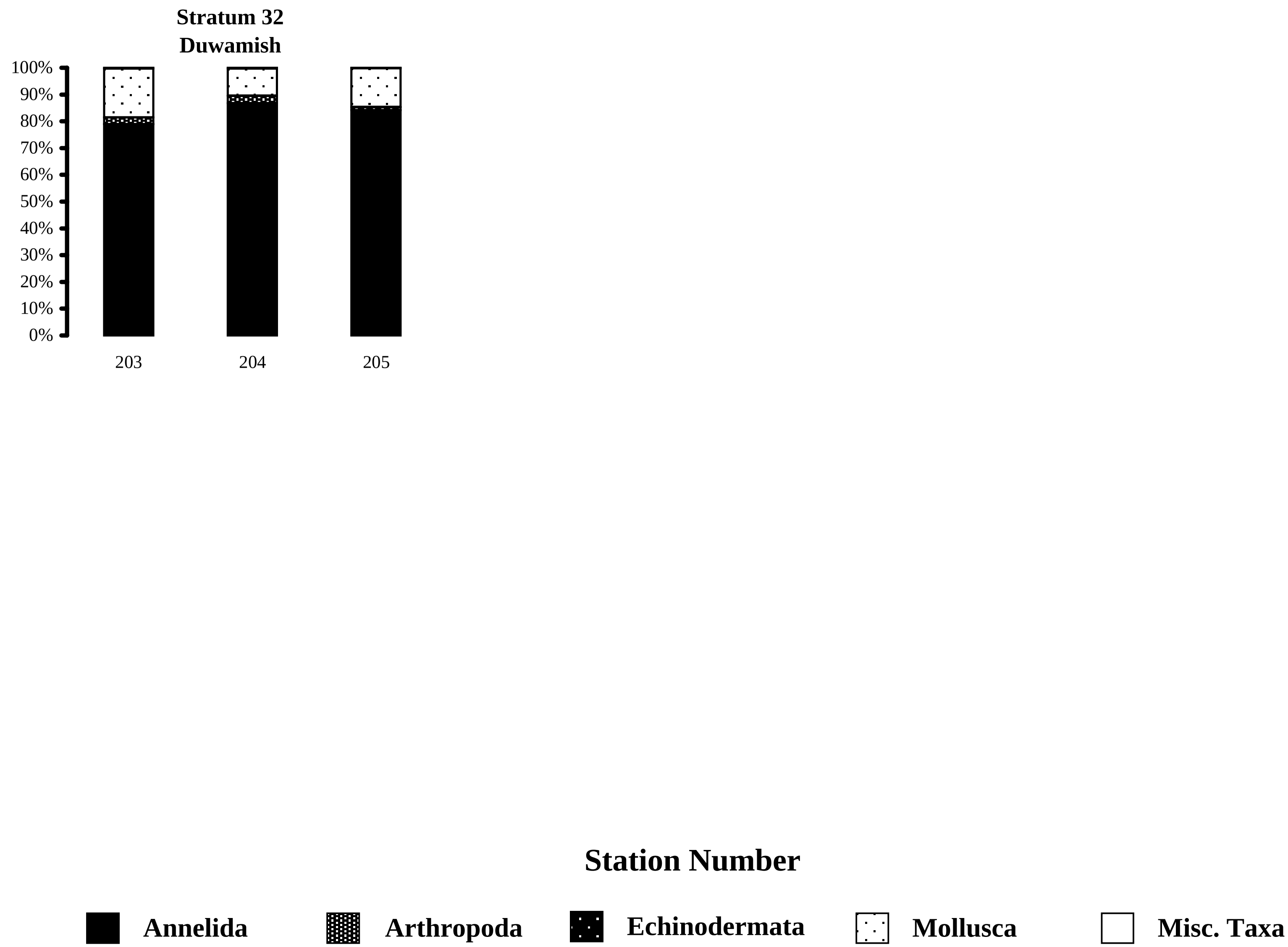
Appendix F. continued.



Appendix F. continued.



Appendix F. continued.



Appendix G

Infaunal taxa eliminated from the final 1998 central Puget Sound benthic infaunal database.

Appendix G. Infaunal taxa eliminated from the 1998 central Puget Sound benthic infaunal database.

Elimination Criteria	Phylum	Class	Family	Taxon
Incidental[1]	Arthropoda		Argulidae	Argulidae
			Caligidae	Caligidae
		Cirripedia	Balanidae	Balanus glandula
				Balanus nubilus
				Balanus sp.
		Copepoda	Ascidocolidae	Ascidocolidae
		Malacostraca	Caprellidae	Caprellidea juv.
			Hyperiidae	Parathemisto pacifica
				Themisto pacifica
			Pinnotheridae	Pinnotheridae megalopae larvae
Meiofauna[2]	Arthropoda	Copepoda		Calanoida
				Harpacticoida
				Orthopsyllus linearis (Harpacticoida)
	Nematoda			Nematoda
Presence/Absence[3]	Bryozoa	Gymnolaemata	Alcyonidiidae	Alcyonidium sp.
			Alderinidae	Copidozoum tenuirostre
			Arachnidiidae	Nolella sp.
			Bicellariellidae	Dendrobeania lichenoides
			Bugulidae	Bugula sp.
				Caulibugula sp.
			Celleporidae	Celleporina robertsoniae
			Chapperiellidae	Chapperiella sp.
			Hippothoidae	Hippothoa hyalina
			Smittinidae	Smittina sp.
			Vesiculariidae	Bowerbankia gracilis

Appendix G. Continued.

Elimination Criteria	Phylum	Class	Family	Taxon
		Stenolaemata	Crisiidae	Crisia sp.
			Tubuliporidae	Tubulipora sp.
	Chordata	Ascidiacea	Clavelinidae	Distaplia sp.
	Cnidaria	Hydrozoa	Bougainvilliidae	Perigonimus sp.
			Calycellidae	Calycella sp.
			Campanulariidae	Campanulariidae
				Clytia sp.
			Eudendriidae	Eudendriidae
			Pandeidae	Pandeidae
			Sertulariidae	Abietinaria sp.
			Tubulariidae	Tubulariidae
	Entoprocta		Barentsiidae	Barentsia benedeni
				Barentsia sp.
			Pedicellinidae	Myosoma spinosa
	Porifera	Calcerea	Grantiidae	Leucandra sp.
		Demospongiae		Demospongiae
			Myxillidae	Myxilla incrustans

Incidental[1]: organisms caught which are not soft sediment infaunal invertebrates -e.g., hard substrate dwellers, larval species, etc.
Meiofauna[2]: organisms which are smaller than the infaunal fracation but accidentally caught by the 1 mm screen.
Presence/absence[3]: organisms, such as colonial species, for which a count of individuals cannot be made.

Appendix H

Triad data - Results of selected toxicity, chemistry, and infaunal analysis for all 1998 central Puget Sound stations.

Appendix H. Triad data - Results of selected, toxicity, chemistry, and infaunal analysis for all 1998 central Puget Sound stations.

Stratum, Sample, Location	Number of ERLs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
1, 106, South Port Townsend		0.07		4-Methylphenol	4-Methylphenol	93.88	*	118.63		1.37		7.1		302	62	0.849	20	149	47	95	8	3	Acila castrensis	37
																							Paraprionospio pinnata	36
																							Eudorella (Tridentata) pacifica	20
																							Parvilucina tenuisculpta	17
																							Scoletoma luti	13
																							Lumbrineris californiensis	12
																							Rochefortia tumida	11
																							Nutricola lordi	11
																							Prionospio steenstrupi	10
																							Heterophoxus affinis	7
1, 107, South Port Townsend	3	0.24		4-Methylphenol	4-Methylphenol	100.00		116.97		3.07		5.7		580	81	0.822	24	292	66	218	3	1	Acila castrensis	119
																							Pinnixa schmitti	31
																							Spiochaetopterus costarum	25
																							Lumbrineris cruzensis	23
																							Mediomastus sp.	20
																							Axinopsida serricata	20
																							Prionospio (Minuspio) lighti	19
																							Paraprionospio pinnata	16
																							Parvilucina tenuisculpta	16
																							Amage anops	16
1, 108, South Port Townsend		0.09		4-Methylphenol	4-Methylphenol	100.00		118.16		13.30		4.9		707	47	0.596	6	99	73	106	421	8	Amphiodia urtica/periercta complex	309
																							Amphiodia sp.	107
																							Heterophoxus affinis	41
																							Terebellides reishi	37
																							Pholoe sp. N1	26
																							Ennucula tenuis	25
																							Eudorella (Tridentata) pacifica	20
																							Acila castrensis	18
																							Rochefortia tumida	13
																							Axinopsida serricata	12

Appendix H.   Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
2, 109, Port Townsend	1	0.08		4-Methylphenol	4-Methylphenol	93.88		116.73		10.67		1.2		702	131	0.835	34	333	181	161	3	24	Microclymene caudata	82
																							Alvania compacta	44
																							Cheirimedeia zotea	34
																							Gammaropsis ellisi	28
																							Magelona longicornis	26
																							Acila castrensis	26
																							Heterophoxus conlanae	25
																							Gattyana cirrosa	23
																							Cyclocardia ventricosa	20
																							Pholoides aspera	17
2, 110, Port Townsend		0.06				97.96		116.73		44.67		1.2		410	68	0.794	18	96	67	224	17	6	Nutricola lordi	97
																							Rochefortia tumida	26
																							Tellina modesta	22
																							Parvilucina tenuisculpta	19
																							Chaetozone nr. setosa	18
																							Gammaropsis thompsoni	17
																							Scoloplos armiger	16
																							Tellina nuculoides	14
																							Dendraster excentricus	14
																							Galathowenia oculata	9
2, 111, Port Townsend		0.07		4-Methylhenol	4-Methylphenol	89.80		115.30		17.07		4.3		807	111	0.768	23	479	42	268	7	11	Nutricola lordi	121
																							Microclymene caudata	85
																							Terebellides reishi	82
																							Axinopsida serricata	58
																							Maldane sarsi	44
																							Mediomastus sp.	24
																							Magelona longicornis	22
																							Parvilucina tenuisculpta	20
																							Prionospio steenstrupi	19
																							Apistobranchus ornatus	18

Appendix H. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
4, 112, South Admiralty Inlet		0.08				96.94		111.98		3.13		4.3		2325	176	0.540	17	758	1349	133	26	59	Erichthonius rubricornis	1198
																							Microclymene caudata	135
																							Oligochaeta	57
																							Pholoides aspera	40
																							Mediomastus sp.	39
																							Maldanidae sp. indet.	31
																							Exogone (E.) lourei	31
																							Ampelisca sp. A	28
																							Crepipatella dorsata	28
																							Cirratulus spectabilis	24
4, 116, South Admiralty Inlet		0.06				101.02		118.40		23.57		0.4		554	53	0.705	8	95	197	254	3	5	Rhepoxynius daboius	94
																							Pinnixa schmitti	85
																							Tellina modesta	82
																							Axinopsida serricata	49
																							Rochefortia tumida	36
																							Nutricola lordi	34
																							Parvilucina tenuisculpta	28
																							Scoloplos armiger	24
																							Leitoscoloplos pugettensis	16
																							Mediomastus sp.	10
4, 117, South Admiralty Inlet	1	0.06				95.92		117.92		18.60		0.6		227	50	0.807	15	78	60	84	0	5	Nutricola lordi	53
																							Photis bifurcata	22
																							Orchomene cf. pinguis	14
																							Scoloplos armiger	12
																							Leitoscoloplos pugettensis	10
																							Dipolydora socialis	10
																							Pinnixa schmitti	9
																							Parvilucina tenuisculpta	9
																							Rochefortia tumida	7
																							Rhepoxynius abronius	6

Appendix H. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
5, 118, Possession Sound	3	0.13		4-Methylphenol	4-Methylphenol	93.41		116.97		4.87		9.3		110	46	0.910	19	67	14	19	4	6	Euclymeninae	12
																							Eudorella (Tridentata) pacifica	7
																							Levinsenia gracilis	7
																							Adontorhina cyclia	7
																							Leitoscoloplos pugettensis	5
																							Cossura bansei	5
																							Spiophanes berkeleyorum	5
																							Scoletoma luti	4
																							Molpadia intermedia	4
																							Axinopsida serricata	4
5, 119, Possession Sound		0.06				97.92		117.68		30.80		0.7		197	35	0.727	8	86	85	17	1	8	Rhepoxynius daboius	60
																							Spiophanes bombyx	32
																							Scoloplos armiger	18
																							Pinnixa schmitti	16
																							Prionospio steenstrupi	9
																							Tellina modesta	6
																							Carinoma mutabilis	5
																							Pholoe sp. N1	5
																							Spiophanes berkeleyorum	5
																							Nephtys ferruginea	4
5, 120, Possession Sound	1	0.07				102.08		117.92		23.27		0.5		201	33	0.727	6	92	80	29	0	0	Spiophanes bombyx	49
																							Pinnixa schmitti	44
																							Rhepoxynius daboius	25
																							Tellina modesta	13
																							Prionospio steenstrupi	12
																							Orchomene pacificus	8
																							Leitoscoloplos pugettensis	5
																							Nephtys ferruginea	4
																							Prionospio (Minuspio) lighti	3
																							Cheirimedeia zotea	3
6, 121, Central Basin		0.06				89.01		115.54		8.67		2.1		1272	60	0.577	5	107	677	475	0	13	Euphilomedes carcharodonta	517
																							Solamen columbiana	194
																							Lirobittium sp.	101
																							Cheirimedeia cf. macrocarpa	89
																							Parvilucina tenuisculpta	71
																							Nutricola lordi	41
																							Spiophanes bombyx	24
																							Rochefortia tumida	17
																							Orchomene cf. pinguis	15
																							Rhepoxynius abronius	15

Appendix H. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
6, 122, Central Basin	1	0.11		4-Methylphenol	4-Methylphenol	98.90		117.68		2.97		9		240	46	0.841	14	82	53	92	1	12	Axinopsida serricata	36
																							Macoma carlottensis	19
																							Macoma sp.	18
																							Euphilomedes producta	15
																							Ampharete acutifrons	13
																							Eudorella (Tridentata) pacifica	13
																							Prionospio (Minuspio) lighti	12
																							Spiophanes berkeleyorum	12
																							Harpiniopsis fulgens	12
																							Parvilucina tenuisculpta	9
6, 123, Central Basin	1	0.10		4-Methylphenol	4-Methylphenol	85.71	*	117.92		5.37		6.1		314	31	0.696	5	30	127	147	3	7	Macoma carlottensis	80
																							Euphilomedes producta	55
																							Eudorella (Tridentata) pacifica	54
																							Macoma sp.	42
																							Lirobittium sp.	8
																							Prionospio (Minuspio) lighti	7
																							Axinopsida serricata	7
																							Nephtys cornuta	6
																							Paranemertes californica	5
																							Dyopedos arcticus	5
7, 124, Port Madison		0.07				105.68		117.44		2.80		3.2		729	73	0.732	12	182	212	138	190	7	Euphilomedes carcharodonta	117
																							Amphiodia sp.	106
																							Amphiodia urtica/periercta complex	78
																							Pinnixa schmitti	59
																							Parvilucina tenuisculpta	49
																							Axinopsida serricata	34
																							Mediomastus sp.	24
																							Euphilomedes producta	20
																							Polycirrus californicus	19
																							Rhepoxynius boreovariatus	16

Appendix H. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
7, 125, Port Madison		0.08				101.14		116.97		2.97		4.7		852	87	0.758	14	280	319	135	103	15	Euphilomedes carcharodonta	123
																							Euphilomedes producta	89
																							Amphiodia urtica/periercta complex	74
																							Polycirrus californicus	64
																							Pinnixa schmitti	46
																							Rhepoxynius boreovariatus	43
																							Mediomastus sp.	41
																							Axinopsida serricata	28
																							Amphiodia sp.	25
																							Parvilucina tenuisculpta	25
7, 126, Port Madison		0.05				98.86		116.97		48.70		2.4		637	93	0.777	18	219	176	130	101	11	Amphiodia urtica/periercta complex	83
																							Rhepoxynius boreovariatus	69
																							Euphilomedes carcharodonta	46
																							Polycirrus californicus	45
																							Axinopsida serricata	38
																							Euphilomedes producta	35
																							Polycirrus sp.	31
																							Parvilucina tenuisculpta	31
																							Pinnixa schmitti	16
																							Amphiodia sp.	15
8, 127, West Point		0.14				103.41		118.63		3.73		17	++	447	51	0.782	9	149	156	137	0	5	Euphilomedes producta	57
																							Axinopsida serricata	49
																							Macoma carlottensis	40
																							Dyopedos sp.	39
																							Ampharete cf. crassiseta	33
																							Nephtys cornuta	31
																							Levinsenia gracilis	23
																							Macoma sp.	18
																							Eudorella (Tridentata) pacifica	18
																							Cossura pygodactylata	17

Appendix H. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
8, 128, West Point	16	0.26				95.45		117.68		24.67		71.1	+++	568	68	0.789	11	201	139	222	1	5	Axinopsida serricata	152
																							Euphilomedes producta	121
																							Levinsenia gracilis	55
																							Macoma carlottensis	40
																							Spiophanes berkeleyorum	30
																							Ampharete cf. crassiseta	16
																							Prionospio (Minuspio) lighti	15
																							Cossura pygodactylata	12
																							Macoma sp.	12
																							Chaetozone commonalis	9
8, 129, West Point	2	0.14				95.45		118.63		10.37		19.1	++	424	62	0.642	7	154	118	136	1	15	Euphilomedes producta	86
																							Axinopsida serricata	54
																							Ampharete cf. crassiseta	37
																							Levinsenia gracilis	27
																							Macoma carlottensis	20
																							Macoma sp.	18
																							Parvilucina tenuisculpta	17
																							Nemocardium centifilosum	15
																							Spiophanes berkeleyorum	14
																							Leptoplanidae	9
8, 113, West Point		0.09		4-Methylphenol	4-Methylphenol	95.92		118.16		2.90		11.7	++	231	37	0.766	13	85	50	91	2	3	Axinopsida serricata	56
																							Euphilomedes producta	28
																							Levinsenia gracilis	20
																							Prionospio (Minuspio) lighti	18
																							Parvilucina tenuisculpta	14
																							Macoma carlottensis	13
																							Ampharete cf. crassiseta	9
																							Pinnixa schmitti	9
																							Nephtys ferruginea	7
																							Cossura pygodactylata	6
9, 130, Eagle Harbor	17	0.33				96.59		117.92		1.97		48.3	+++	863	95	0.732	17	541	93	218	4	7	Aphelochaeta sp. N1	202
																							Parvilucina tenuisculpta	110
																							Axinopsida serricata	40
																							Scoletoma luti	36
																							Mediomastus sp.	32
																							Dipolydora socialis	31
																							Euphilomedes carcharodonta	30
																							Chaetozone nr. setosa	29
																							Nephtys cornuta	28
																							Eudorella (Tridentata) pacifica	23

Appendix H. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
9, 131, Eagle Harbor	19	0.36				103.41		118.87		0.87		96.5	+++	762	56	0.671	8	339	244	172	3	4	Eudorella (Tridentata) pacifica	196
																							Aphelochaeta sp. N1	139
																							Nutricola lordi	72
																							Aphelochaeta monilaris	60
																							Terebellides californica	38
																							Axinopsida serricata	35
																							Protomedeia grandimana	24
																							Chaetozone nr. setosa	22
																							Euphilomedes carcharodonta	21
																							Macoma sp.	18
9, 132, Eagle Harbor	5	0.14				100.00		118.40		1.77		14.7	++	1455	82	0.490	5	1143	201	105	2	4	Aphelochaeta sp. N1	798
																							Euphilomedes carcharodonta	172
																							Mediomastus sp.	62
																							Scoletoma luti	43
																							Notomastus tenuis	32
																							Lumbrineris californiensis	31
																							Axinopsida serricata	22
																							Leitoscoloplos pugettensis	17
																							Mya arenaria	17
																							Nutricola lordi	14
10, 133, Central Sound		0.07				97.80		105.44		12.13		8.7		531	77	0.734	16	124	178	179	32	18	Axinopsida serricata	116
																							Euphilomedes producta	67
																							Euphilomedes carcharodonta	63
																							Parvilucina tenuisculpta	37
																							Amphiodia urtica/periercta complex	23
																							Pinnixa occidentalis	17
																							Mediomastus sp.	12
																							Rhepoxynius bicuspidatus	10
																							Aricidea (Allia) ramosa	9
																							Amphiodia sp.	8

Appendix H. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
10, 134, Central Sound		0.06				94.74	*	105.66		4.60		7.5		363	54	0.679	9	76	184	87	5	11	Euphilomedes carcharodonta	114
																							Parvilucina tenuisculpta	52
																							Euphilomedes producta	50
																							Mediomastus sp.	15
																							Axinopsida serricata	11
																							Rochefortia tumida	10
																							Rhepoxynius bicuspidatus	10
																							Lucinoma annulatum	9
																							Prionospio steenstrupi	7
																							Pectinaria californiensis	6
10, 135, Central Sound		0.06				94.74		106.08		28.63		13.5	++	304	73	0.855	22	180	43	70	3	8	Prionospio steenstrupi	32
																							Mediomastus sp.	26
																							Magelona longicornis	24
																							Astyris gausapata	16
																							Parvilucina tenuisculpta	15
																							Rhepoxynius daboius	12
																							Euphilomedes carcharodonta	11
																							Prionospio (Minuspio) lighti	10
																							Rochefortia tumida	9
																							Axinopsida serricata	9
11, 136, Central Sound	3	0.18				93.55		106.72		6.30		13.7	++	198	38	0.809	11	63	71	53	0	11	Euphilomedes producta	35
																							Prionospio (Minuspio) lighti	34
																							Macoma carlottensis	16
																							Axinopsida serricata	14
																							Levinsenia gracilis	11
																							Eudorella (Tridentata) pacifica	10
																							Macoma sp.	8
																							Diastylis santamariensis	6
																							Paranemertes californica	5
																							Dyopedos sp.	5
11, 137, Central Sound	5	0.20				101.08		105.44		9.93		15.7	++	230	40	0.820	10	85	67	66	0	12	Euphilomedes producta	29
																							Axinopsida serricata	28
																							Sigambra tentaculata	22
																							Levinsenia gracilis	17
																							Macoma carlottensis	17
																							Prionospio (Minuspio) lighti	14
																							Parvilucina tenuisculpta	13
																							Spiophanes berkeleyorum	12
																							Eudorella (Tridentata) pacifica	11
																							Eudorellopsis integra	10

Appendix H. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
11, 138, Central Sound	4	0.15				106.45		105.02		2.43		17.1	++	168	40	0.821	13	50	79	28	2	9	Eudorella (Tridentata) pacifica	30
																							Euphilomedes producta	29
																							Prionospio (Minuspio) lighti	10
																							Macoma carlottensis	8
																							Levinsenia gracilis	7
																							Trochochaeta multisetosa	7
																							Eudorellopsis integra	7
																							Axinopsida serricata	6
																							Macoma sp.	6
																							Glycera nana	6
12, 139, East Passage	2	0.10				94.44		106.51		21.13		17.8	++	337	55	0.719	10	81	94	151	2	9	Axinopsida serricata	66
																							Macoma carlottensis	59
																							Euphilomedes producta	43
																							Eudorellopsis integra	36
																							Levinsenia gracilis	16
																							Prionospio (Minuspio) lighti	10
																							Parvilucina tenuisculpta	9
																							Paraprionospio pinnata	7
																							Diastylis santamariensis	6
																							Spiophanes berkeleyorum	6
12, 140, East Passage	4	0.13		4-Methylphenol	4-Methylphenol	97.78		105.44		3.63		23.8	++	144	35	0.832	11	63	46	29	2	4	Axinopsida serricata	22
																							Levinsenia gracilis	20
																							Eudorella (Tridentata) pacifica	17
																							Cossura bansei	12
																							Spiophanes berkeleyorum	9
																							Euphilomedes producta	8
																							Eudorellopsis integra	7
																							Prionospio (Minuspio) lighti	5
																							Macoma carlottensis	4
																							Paraprionospio pinnata	3
12, 141, East Passage		0.06				80.00		102.45		64.10		5.8		265	79	0.909	33	177	38	33	3	14	Pionosyllis uraga	23
																							Lumbrineris californiensis	19
																							Nicomache lumbricalis	11
																							Pholoides aspera	9
																							Demonax rugosus	9
																							Aricidea (Acmira) lopezi	8
																							Tritella pilimana	7
																							Pista elongata	7
																							Syllis (Ehlersia) heterochaeta	7
																							Nemocardium centifilosum	6

Appendix H. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
13, 142, Liberty Bay	4	0.13				94.32		105.44		5.27		16.7		325	26	0.702	6	109	102	4	107	3	Amphiodia urtica/periercta complex	96
																							Pinnixa schmitti	79
																							Aphelochaeta sp. N1	25
																							Nephtys cornuta	22
																							Eudorella (Tridentata) pacifica	16
																							Pholoe sp. N1	15
																							Spiophanes berkeleyorum	15
																							Amphiodia sp.	11
																							Terebellides californica	7
																							Heteromastus filobranchus	5
13, 143, Liberty Bay	4	0.16				96.59		105.87		1.47		24.8	++	309	28	0.740	7	171	75	32	31	0	Aphelochaeta sp. N1	84
																							Pinnixa occidentalis	37
																							Eudorella (Tridentata) pacifica	34
																							Amphiodia urtica/periercta complex	29
																							Nephtys cornuta	25
																							Pholoe sp. N1	22
																							Turbonilla sp.	19
																							Paraprionospio pinnata	10
																							Nutricola lordi	8
																							Spiophanes berkeleyorum	8
13, 144, Liberty Bay	4	0.16				92.05		106.30		1.17		27.7	++	293	28	0.693	7	56	105	40	90	2	Pinnixa schmitti	90
																							Amphiodia urtica/periercta complex	79
																							Eudorella (Tridentata) pacifica	14
																							Paraprionospio pinnata	13
																							Pholoe sp. N1	12
																							Acteocina culcitella	10
																							Amphiodia sp.	10
																							Acila castrensis	8
																							Sigambra tentaculata	8
																							Nephtys cornuta	7

Appendix H. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
14, 145, Keyport		0.04				105.68		106.08		2.83		2.5		354	48	0.869	16	179	61	107	3	4	Aphelochaeta sp. N1	34
																							Nutricola lordi	31
																							Leitoscoloplos pugettensis	24
																							Scoloplos acmeceps	22
																							Ampharete labrops	21
																							Alvania compacta	19
																							Scoletoma luti	16
																							Rochefortia tumida	16
																							Protomedeia grandimana	14
																							Mediomastus sp.	13
14, 146, Keyport	4	0.12				103.41		104.59		1.10		32	++	650	28	0.560	3	63	200	34	353	0	Amphiodia urtica/periercta complex	254
																							Pinnixa schmitti	161
																							Amphiodia sp.	94
																							Eudorella (Tridentata) pacifica	39
																							Acila castrensis	21
																							Pholoe sp. N1	19
																							Paraprionospio pinnata	9
																							Nephtys cornuta	9
																							Terebellides californica	5
																							Aphelochaeta sp. N1	5
14, 147, Keyport		0.07				98.86		105.66		5.63		5.6		543	85	0.748	17	354	25	149	4	11	Aphelochaeta sp. N1	124
																							Ampharete labrops	58
																							Alvania compacta	36
																							Nutricola lordi	30
																							Scoloplos acmeceps	28
																							Leitoscoloplos pugettensis	28
																							Mediomastus sp.	15
																							Glycinde polygnatha	13
																							Odostomia sp.	12
																							Astyris gausapata	12

Appendix H. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
15, 148, NW Bainbridge Island	3	0.12		4-Methylphenol	4-Methylphenol	98.86		105.66		0.94		26.4	++	349	33	0.763	8	112	31	69	135	2	Amphiodia sp.	82
																							Acteocina culcitella	48
																							Amphiodia urtica/periercta complex	44
																							Eudorella (Tridentata) pacifica	24
																							Spiophanes berkeleyorum	21
																							Lumbrineris cruzensis	16
																							Terebellides californica	14
																							Pholoe sp. N1	13
																							Heteromastus filobranchus	12
																							Acila castrensis	9
15, 149, NW Bainbridge Island		0.04				95.45		103.95		1.09		6.6		810	73	0.665	13	204	112	466	13	15	Alvania compacta	290
																							Rochefortia tumida	93
																							Phyllochaetopterus prolifica	61
																							Heptacarpus stimpsoni	52
																							Macoma yoldiformis	23
																							Aoroides intermedius	20
																							Dipolydora socialis	14
																							Caulleriella pacifica	11
																							Tellina modesta	11
																							Scoloplos sp.	11
15, 150, NW Bainbridge Island		0.07				93.18		105.87		1.23		9.3		435	44	0.702	7	136	17	127	148	7	Amphiodia urtica/periercta complex	89
																							Acteocina culcitella	84
																							Amphiodia sp.	55
																							Pholoe sp. N1	55
																							Acila castrensis	24
																							Lumbrineris cruzensis	14
																							Pinnixa occidentalis	12
																							Heteromastus filobranchus	12
																							Spiophanes berkeleyorum	9
																							Cossura pygodactylata	6

Appendix H. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
16, 151, SW Bainbridge Island	5	0.18		Benzyl Alcohol	Benzyl Alcohol	98.95		106.30		0.82		31.6	++	337	37	0.716	6	99	14	70	144	10	Amphiodia sp.	69
																							Amphiodia urtica/periercta complex	64
																							Pholoe sp. N1	36
																							Acila castrensis	35
																							Terebellides californica	34
																							Acteocina culcitella	17
																							Amphiuridae	11
																							Pinnixa occidentalis	9
																							Odostomia sp.	8
																							Cossura pygodactylata	6
16, 152, SW Bainbridge Island		0.08				98.95		105.44		4.60		7.6		859	87	0.690	15	165	122	475	86	11	Acila castrensis	289
																							Euphilomedes carcharodonta	70
																							Amphiodia urtica/periercta complex	50
																							Axinopsida serricata	33
																							Ennucula tenuis	27
																							Macoma sp.	26
																							Amphiodia sp.	23
																							Odostomia sp.	23
																							Alvania compacta	18
																							Astyris gausapata	18
16, 153, SW Bainbridge Island	4	0.19				100.00		104.38		1.97		27.9	++	243	40	0.837	14	83	8	87	58	7	Axinopsida serricata	40
																							Amphiodia urtica/periercta complex	35
																							Amphiodia sp.	23
																							Levinsenia gracilis	11
																							Sigambra tentaculata	11
																							Pholoe sp. N1	10
																							Cossura bansei	10
																							Yoldia hyperborea	8
																							Acteocina culcitella	8
																							Acila castrensis	8

Appendix H. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
17, 154, Rich Passage		0.04				97.89		104.80		7.80		1.9		659	99	0.077	23	199	41	395	5	19	Nutricola lordi	138
																							Alvania compacta	75
																							Tellina modesta	44
																							Parvilucina tenuisculpta	24
																							Macoma yoldiformis	22
																							Lirularia lirulata	22
																							Spiochaetopterus costarum	20
																							Lumbrineris californiensis	14
																							Rochefortia tumida	14
																							Protodorvillea gracilis	12
17, 155, Rich Passage		0.04				98.95		105.66		20.27		1.6		951	68	0.606	6	93	138	709	0	11	Nutricola lordi	290
																							Tellina modesta	220
																							Euphilomedes carcharodonta	79
																							Rochefortia tumida	57
																							Parvilucina tenuisculpta	57
																							Protomedeia grandimana	23
																							Euclymeninae	18
																							Lirobittium sp.	15
																							Turbonilla sp.	13
																							Astyris gausapata	12
17, 156, Rich Passage		0.07				97.89		105.02		30.17		10		573	102	0.815	24	234	189	105	19	26	Pinnixa occidentalis	64
																							Euphilomedes carcharodonta	62
																							Rochefortia tumida	37
																							Mediomastus sp.	29
																							Astyris gausapata	23
																							Prionospio (Minuspio) lighti	22
																							Rhepoxynius daboius	21
																							Syllis (Ehlersia) hyperioni	20
																							Dipolydora socialis	17
																							Amphiodia urtica/periercta complex	15

Appendix H. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
18, 157, Port Orchard		0.07				102.20		113.00		3.20		14.1	++	808	90	0.673	12	163	159	443	37	6	Acila castrensis	246
																							Euphilomedes carcharodonta	119
																							Nutricola lordi	42
																							Prionospio (Minuspio) lighti	30
																							Odostomia sp.	28
																							Astyris gausapata	27
																							Axinopsida serricata	24
																							Amphiodia urtica/periercta complex	22
																							Macoma sp.	20
																							Parvilucina tenuisculpta	20
18, 158, Port Orchard		0.05				84.62	*	113.00		4.70		7.6		631	113	0.763	27	241	84	265	26	15	Alvania compacta	173
																							Phyllochaetopterus prolifica	39
																							Lumbrineris californiensis	20
																							Magelona longicornis	19
																							Protomedeia grandimana	18
																							Spiochaetopterus costarum	16
																							Corophium (Monocorophium) insidiosum	14
																							Amphipholis squamata	14
																							Nutricola lordi	14
																							Parvilucina tenuisculpta	12
18, 159, Port Orchard		0.06				92.00		97.00		2.27		12.4	++	563	99	0.819	28	137	122	241	46	17	Alvania compacta	78
																							Rochefortia tumida	64
																							Aoroides columbiae	45
																							Amphipholis squamata	23
																							Crepipatella dorsata	16
																							Foxiphalus similis	14
																							Lirularia lirulata	14
																							Micropodarke dubia	13
																							Harmothoe imbricata	12
																							Heterophoxus conlanae	12

Appendix H. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
19, 160, Sinclair Inlet	9	0.35	Mercury	Mercury	Mercury	99.00		2.00	**	0.81		29.4	++	149	21	0.633	4	132	3	9	0	5	Aphelochaeta sp. N1	73
																							Paraprionospio pinnata	23
																							Terebellides californica	11
																							Nephtys cornuta	9
																							Micrura sp.	5
																							Chaetozone nr. setosa	4
																							Podarke pugettensis	3
																							Odostomia sp.	3
																							Crangon alaskensis	2
																							Spiophanes berkeleyorum	2
19, 161, Sinclair Inlet	7	0.27		Mercury	Mercury	104.40		103.00		0.82		44.5	+++	1283	32	0.387	2	1165	52	41	24	1	Aphelochaeta sp. N1	856
																							Nephtys cornuta	209
																							Eudorella (Tridentata) pacifica	34
																							Lumbrineris cruzensis	33
																							Terebellides californica	23
																							Amphiodia urtica/periercta complex	18
																							Axinopsida serricata	15
																							Pinnixa schmitti	15
																							Odostomia sp.	12
																							Paraprionospio pinnata	8
19, 162, Sinclair Inlet	8	0.30	Mercury	Mercury	Mercury	86.81		113.00		1.63		35.5	++	559	44	0.706	7	220	166	64	105	4	Eudorella (Tridentata) pacifica	102
																							Amphiodia urtica/periercta complex	96
																							Aphelochaeta monilaris	90
																							Pinnixa schmitti	44
																							Acila castrensis	42
																							Phyllochaetopterus prolifica	38
																							Lumbrineris cruzensis	21
																							Pholoe sp. N1	14
																							Terebellides californica	13
																							Amphiodia sp.	9

Appendix H. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
20, 163, Sinclair Inlet	8	0.44	Mercury	Mercury	Mercury	93.41		113.00		1.02		27.7	++	565	32	0.686	6	326	113	33	86	7	Aphelochaeta sp. N1	186
																							Amphiodia urtica/periercta complex	83
																							Eudorella (Tridentata) pacifica	74
																							Pinnixa schmitti	35
																							Lumbrineris cruzensis	29
																							Terebellides californica	26
																							Pholoe sp. N1	25
																							Aphelochaeta monilaris	17
																							Cossura pygodactylata	11
																							Odostomia sp.	9
20, 164, Sinclair Inlet	9	0.42	Mercury	Mercury	Mercury	101.10		112.00		1.50		64.9	+++	1336	53	0.498	5	1067	132	108	21	8	Aphelochaeta sp. N1	782
																							Eudorella (Tridentata) pacifica	82
																							Scoletoma luti	80
																							Prionospio (Minuspio) lighti	42
																							Pinnixa schmitti	41
																							Odostomia sp.	32
																							Nutricola lordi	26
																							Aphelochaeta monilaris	25
																							Spiophanes berkeleyorum	23
																							Amphiodia urtica/periercta complex	20
20, 165, Sinclair Inlet	11	0.55	Mercury	Mercury	Mercury	100.00		81.00	**	6.83		39.4	+++	663	36	0.689	6	269	277	34	73	10	Eudorella (Tridentata) pacifica	199
																							Amphiodia urtica/periercta complex	73
																							Pinnixa schmitti	73
																							Lumbrineris cruzensis	70
																							Prionospio (Minuspio) lighti	57
																							Aphelochaeta sp. N1	36
																							Acila castrensis	21
																							Pholoe sp. N1	19
																							Aphelochaeta monilaris	14
																							Spiophanes berkeleyorum	14

Appendix H. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
21, 166, Port Washington Narrows		0.06				104.44		111.00		3.40		6.5		651	85	0.789	20	196	162	270	5	18	Euphilomedes carcharodonta	92
																							Alvania compacta	79
																							Nutricola lordi	58
																							Aphelochaeta sp. N1	29
																							Rochefortia tumida	28
																							Phyllochaetopterus prolifica	28
																							Lumbrineris californiensis	24
																							Astyris gausapata	24
																							Nassarius mendicus	19
																							Westwoodilla caecula	15
21, 167, Port Washington Narrows		0.08				46.67	**	82.00	*	3.30		9.9		826	79	0.691	10	412	156	221	22	15	Alvania compacta	193
																							Aphelochaeta sp. N1	100
																							Phyllochaetopterus prolifica	88
																							Ampelisca lobata	56
																							Pontogeneia rostrata	48
																							Circeis sp.	44
																							Scoletoma luti	31
																							Leitoscoloplos pugettensis	28
																							Lumbrineris californiensis	24
																							Deflexilodes similis	19
21, 168, Port Washington Narrows	7	0.17				96.67		69.00	**	0.65		32.3	++	1232	48	0.261	1	1103	30	93	2	4	Aphelochaeta sp. N1	1023
																							Alvania compacta	35
																							Odostomia sp.	21
																							Scoletoma luti	13
																							Nutricola lordi	12
																							Axinopsida serricata	10
																							Lumbrineris cruzensis	10
																							Ampelisca unsocalae	8
																							Paraprionospio pinnata	8
																							Heterophoxus conlanae	8
22, 169, Dyes Inlet		0.05				101.11		94.00		4.10		3.6		1574	74	0.650	9	1123	248	179	17	7	Phyllochaetopterus prolifica	455
																							Circeis sp.	240
																							Aphelochaeta sp. N1	137
																							Caprella mendax	122
																							Rochefortia tumida	74
																							Scoletoma luti	53
																							Pinnixa schmitti	45
																							Lumbrineris californiensis	39
																							Astyris gausapata	31
																							Euclymene cf. zonalis	27

Appendix H. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
22, 170, Dyes Inlet	10	0.26		Benzyl Alcohol		100.00		101.00		1.04		27.6	++	894	33	0.583	4	266	364	57	200	7	Pinnixa schmitti	271
																							Amphiodia urtica/periercta complex	196
																							Aphelochaeta sp. N1	181
																							Eudorella (Tridentata) pacifica	92
																							Acila castrensis	32
																							Pholoe sp. N1	24
																							Terebellides californica	11
																							Rochefortia tumida	10
																							Prionospio (Minuspio) lighti	8
																							Aphelochaeta monilaris	8
22, 171, Dyes Inlet	10	0.26		Mercury, Benzyl Alcohol	Mercury	101.11		92.00		2.03		30.4	++	1113	39	0.552	4	260	574	48	224	7	Pinnixa schmitti	440
																							Amphiodia urtica/periercta complex	220
																							Eudorella (Tridentata) pacifica	130
																							Terebellides californica	62
																							Prionospio (Minuspio) lighti	57
																							Aphelochaeta sp. N1	49
																							Rochefortia tumida	37
																							Pholoe sp. N1	37
																							Nephtys cornuta	18
																							Lumbrineris cruzensis	7
23, 172, Outer Elliott Bay	5	0.20				102.22		94.00		2.13		17.8	++	188	43	0.809	13	69	48	60	0	11	Axinopsida serricata	46
																							Euphilomedes producta	17
																							Spiophanes berkeleyorum	14
																							Heterophoxus affinis	10
																							Sigambra tentaculata	9
																							Levinsenia gracilis	8
																							Paranemertes californica	7
																							Eudorellopsis integra	6
																							Macoma sp.	6
																							Cossura bansei	6

Appendix H. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
23, 173, Outer Elliott Bay	7	0.28				106.67		102.00		4.97		19.8	++	470	56	0.591	6	174	56	230	5	5	Axinopsida serricata	216
																							Spiochaetopterus costarum	52
																							Euphilomedes producta	28
																							Spiophanes berkeleyorum	26
																							Eudorellopsis integra	21
																							Levinsenia gracilis	15
																							Cossura bansei	12
																							Ampharete acutifrons	8
																							Sigambra tentaculata	6
																							Prionospio (Minuspio) lighti	5
23, 174, Outer Elliott Bay		0.09		Butylbenzyl-phthalate		96.67		93.00		35.97		10.5		494	127	0.834	38	308	83	64	30	9	Prionospio steenstrupi	73
																							Pholoides aspera	29
																							Dipolydora cardalia	27
																							Euphilomedes carcharodonta	21
																							Magelona berkeleyi	20
																							Nemocardium centifilosum	18
																							Pinnixa schmitti	13
																							Crossaster papposus	13
																							Byblis millsi	11
																							Pentamera pseudopopulifera	11
23, 175, Outer Elliott Bay		0.07				97.78		96.00		5.23		3.3		631	137	0.894	48	352	114	114	28	23	Euphilomedes carcharodonta	36
																							Dipolydora socialis	27
																							Prionospio steenstrupi	24
																							Mediomastus sp.	21
																							Pholoides aspera	18
																							Lumbrineris californiensis	17
																							Nemocardium centifilosum	16
																							Axinopsida serricata	15
																							Parvilucina tenuisculpta	14
																							Pinnixa schmitti	14
24, 176, Shoreline Elliott Bay	5	0.31		Mercury, Benzo(g,h,i) perylene, Phenanthrene, Butylbenzyl-phthalate		92.22		82.00	*	2.27		12.5	++	876	113	0.771	22	501	97	255	12	11	Alvania compacta	132
																							Spiochaetopterus costarum	98
																							Parvilucina tenuisculpta	72
																							Dipolydora cardalia	43
																							Mediomastus sp.	36
																							Euphilomedes carcharodonta	32
																							Lumbrineris californiensis	31
																							Prionospio steenstrupi	27
																							Eumida longicornuta	22
																							Caulleriella pacifica	19

Appendix H. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
24, 177, Shoreline Elliott Bay	2	0.08				101.11		75.00	**	2.57		3.4		1378	61	0.515	4	78	475	822	1	2	Euphilomedes carcharodonta	456
																							Nutricola lordi	440
																							Tellina modesta	100
																							Lirularia lirulata	92
																							Alvania compacta	36
																							Lirobittium sp.	33
																							Clinocardium nuttallii	29
																							Parvilucina tenuisculpta	21
																							Macoma sp.	17
																							Rochefortia tumida	16
24, 178, Shoreline Elliott Bay		0.14				101.11		106.00		86.83		10.7		343	80	0.783	21	179	104	56	1	3	Euphilomedes carcharodonta	70
																							Prionospio steenstrupi	38
																							Magelona longicornis	27
																							Pinnixa schmitti	19
																							Exogone (E.) lourei	14
																							Spiochaetopterus costarum	13
																							Parvilucina tenuisculpta	11
																							Solamen columbiana	10
																							Lyonsia californica	6
																							Nephtys ferruginea	6
25, 179, Shoreline Elliott Bay	13	0.52		Benzo(g,h,i) perylene		95.56		81.00	*	25.10		38.8	+++	478	69	0.731	12	254	83	137	0	4	Levinsenia gracilis	70
																							Prionospio steenstrupi	64
																							Axinopsida serricata	62
																							Euphilomedes carcharodonta	52
																							Parvilucina tenuisculpta	43
																							Euphilomedes producta	22
																							Scoletoma luti	9
																							Aricidea (Acmira) lopezi	9
																							Nephtys ferruginea	9
																							Aphelochaeta sp. N1	8
25, 180, Shoreline Elliott Bay	15	0.57		Benzo(g,h,i) perylene, Indeno(1,2,3-c,d)pyrene		97.85		68.00	**	17.50		34.4	++	639	77	0.793	19	350	66	215	3	5	Parvilucina tenuisculpta	82
																							Prionospio steenstrupi	79
																							Axinopsida serricata	73
																							Euphilomedes producta	39
																							Aphelochaeta sp. N1	23
																							Scoletoma luti	23
																							Levinsenia gracilis	19
																							Notomastus tenuis	18
																							Solamen columbiana	16
																							Pinnixa schmitti	15

Appendix H. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
25, 181, Shoreline Elliott Bay	24	1.59	Benzo(g,h,i)perylene, Total HPAHs, Total PAHs, Total PCBs	Mercury		87.78	*	96.00		17.20		32.8	++	457	85	0.833	27	212	88	142	2	13	Euphilomedes producta	69
																							Axinopsida serricata	55
																							Levinsenia gracilis	19
																							Chaetozone nr. setosa	17
																							Prionospio steenstrupi	17
																							Scoletoma luti	15
																							Macoma carlottensis	12
																							Euclymeninae	12
																							Euphilomedes carcharodonta	11
																							Spiophanes berkeleyorum	10
25, 115, Shoreline Elliott Bay	24	0.83		Benzo(g,h,i) perylene, 4-Methylphenol	4-Methylphenol	96.97		6.00	**	0.79		144.8	+++	1161	43	0.255	1	1092	9	60	0	0	Aphelochaeta sp. N1	962
																							Lumbrineris californiensis	43
																							Turbonilla sp.	35
																							Scoletoma luti	12
																							Spiochaetopterus costarum	12
																							Alvania compacta	10
																							Armandia brevis	9
																							Notomastus tenuis	9
																							Parvilucina tenuisculpta	7
																							Prionospio sp.	6
26, 182, Shoreline Elliott Bay	24	1.36	Mercury, Pyrene, Total LPAHs, Total HPAHs, Total PCBs	Mercury, Benzo(g,h,i) perylene, Fluoranthene, Indeno(1,2,3-c,d)pyrene	Mercury	97.85		83.00	*	26.47		216.1	+++	571	88	0.792	23	309	37	188	21	16	Axinopsida serricata	115
																							Levinsenia gracilis	73
																							Aricidea (Acmira) lopezi	22
																							Euphilomedes producta	18
																							Scoletoma luti	16
																							Spiophanes berkeleyorum	15
																							Prionospio steenstrupi	14
																							Amphiodia urtica/periercta complex	14
																							Nemocardium centifilosum	14
																							Chaetozone nr. setosa	14

Appendix H. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds excceding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
26, 183, Shoreline Elliott Bay	20	0.52		Benzo(a) anthracene, Benzo(a)pyrene, Benzo(g,h,i) perylene, Fluoranthene, Fluorene, Indeno(1,2,3-c,d)pyrene, Phenanthrene, Total fluoranthene, Total HPAHs, Dibenzofuran	Benzo(a)pyrene	100.00		88.00		3.17		107.2	+++	740	105	0.795	23	435	133	159	3	10	Prionospio steenstrupi	79
																							Euphilomedes carcharodonta	65
																							Parvilucina tenuisculpta	61
																							Lumbrineris californiensis	59
																							Axinopsida serricata	53
																							Pinnixa schmitti	27
																							Prionospio (Minuspio) multibranchiata	25
																							Aphelochaeta sp. N1	25
																							Spiochaetopterus costarum	18
																							Scoletoma luti	16
26, 184, Shoreline Elliott Bay	22	1.31	Benzo(a)anthracene, Benzo(a)pyrene, Fluoranthene, Phenanthrene, Pyrene, Total LPAHs, Total PAHs	Benzo(a)pyrene, Benzo(g,h,i) perylene, Fluoranthene, Indeno(1,2,3-c,d)pyrene, Phenanthrene, Total HPAHs, Total fluoranthene	Total Benzo-fluoranthene, Fluoranthene, Total HPAHs, Total PAHs	103.23		84.00	*	7.90		223.2	+++	731	89	0.791	21	488	57	177	2	7	Lumbrineris californiensis	97
																							Prionospio steenstrupi	82
																							Parvilucina tenuisculpta	77
																							Aphelochaeta sp. N1	39
																							Axinopsida serricata	33
																							Alvania compacta	33
																							Euphilomedes carcharodonta	23
																							Nephtys cornuta	19
																							Spiochaetopterus costarum	17
																							Lumbrineris sp.	15
27, 185, Mid Elliott Bay	7	0.39		Bis(2-Ethylhexyl) Phthalate		104.30		120.00		18.20		19.7	++	269	32	0.739	9	106	57	101	1	4	Axinopsida serricata	98
																							Prionospio (Minuspio) lighti	23
																							Levinsenia gracilis	17
																							Spiophanes berkeleyorum	15
																							Eudorellopsis integra	14
																							Anonyx cf. lilljeborgi	12
																							Cossura bansei	10
																							Eudorellopsis longirostris	10
																							Ampharete cf. crassiseta	8
																							Euphilomedes producta	8

Appendix H. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
27, 186, Mid Elliott Bay	13	0.57	Mercury	Mercury	Mercury	101.08		116.00		34.00		54.9	+++	655	70	0.613	9	169	84	392	3	7	Axinopsida serricata	294
																							Euphilomedes producta	56
																							Parvilucina tenuisculpta	26
																							Euphilomedes carcharodonta	26
																							Levinsenia gracilis	22
																							Prionospio steenstrupi	22
																							Nemocardium centifilosum	18
																							Proclea graffii	17
																							Macoma carlottensis	14
																							Aricidea (Acmira) lopezi	13
27, 187, Mid Elliott Bay	12	0.55				107.69		115.00		37.73		26.5	++	334	46	0.473	5	69	30	227	1	7	Axinopsida serricata	222
																							Spiophanes berkeleyorum	11
																							Cossura bansei	8
																							Protomedeia grandimana	7
																							Heterophoxus affinis	6
																							Prionospio (Minuspio) lighti	5
																							Levinsenia gracilis	5
																							Eudorellopsis longirostris	5
																							Scoletoma luti	5
																							Ampharete cf. crassiseta	4
27, 188, Mid Elliott Bay	23	1.47	Benzo(a)pyrene, Phenanthrene, Pyrene, Total LPAHs, Total HPAHs, Total PCBs	Mercury, Benzo(g,h,i) perylene, Fluoranthene, Indeno(1,2,3-c,d)pyrene, Benzyl Alcohol, 2,4-Dimethylphenol	Mercury, 2,4-Dimethylphenol	105.49		115.00		67.17		152.9	+++	825	67	0.507	5	166	72	563	8	16	Axinopsida serricata	471
																							Euphilomedes producta	51
																							Levinsenia gracilis	40
																							Parvilucina tenuisculpta	37
																							Nemocardium centifilosum	22
																							Aricidea (Acmira) lopezi	18
																							Proclea graffii	17
																							Euphilomedes carcharodonta	13
																							Scoletoma luti	12
																							Chaetozone nr. setosa	9

Appendix H. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
28, 189, Mid Elliott Bay	16	0.43				108.79		109.00		9.47		139.8	+++	928	102	0.705	17	361	312	219	28	8	Euphilomedes carcharodonta	222
																							Parvilucina tenuisculpta	148
																							Spiochaetopterus costarum	52
																							Mediomastus sp.	43
																							Pinnixa schmitti	43
																							Prionospio steenstrupi	31
																							Amphiodia urtica/periercta complex	27
																							Notomastus tenuis	21
																							Apistobranchus ornatus	18
																							Magelona longicornis	17
28, 190, Mid Elliott Bay		0.06		Di-N-Butylphthalate		106.59		117.00		5.93		3.6		1717	71	0.445	3	114	909	688	0	6	Euphilomedes carcharodonta	858
																							Nutricola lordi	392
																							Tellina modesta	103
																							Astyris gausapata	50
																							Rochefortia tumida	41
																							Parvilucina tenuisculpta	37
																							Clinocardium nuttallii	21
																							Cheirimedeia cf. macrocarpa	20
																							Lirularia lirulata	16
																							Glycinde armigera	15
28, 191, Mid Elliott Bay	13	0.45				103.30		113.00		179.30		29.1	++	328	57	0.694	12	155	36	132	1	4	Axinopsida serricata	124
																							Levinsenia gracilis	28
																							Maldane sarsi	20
																							Spiophanes berkeleyorum	17
																							Euphilomedes producta	12
																							Chaetozone commonalis	11
																							Prionospio (Minuspio) lighti	7
																							Cossura bansei	7
																							Amage anops	6
																							Onuphis iridescens	6

Appendix H. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
28, 192, Mid Elliott Bay	9	0.36				103.30		107.00		35.17		49.1	+++	883	91	0.706	14	608	112	151	7	5	Microclymene caudata	224
																							Axinopsida serricata	84
																							Euphilomedes producta	73
																							Proclea graffii	66
																							Maldane sarsi	51
																							Levinsenia gracilis	34
																							Tharyx sp. N1 (=nr. parvus)	25
																							Adontorhina cyclia	20
																							Spiophanes berkeleyorum	17
																							Ampharetidae	15
29, 193, Mid Elliott Bay	9	0.37				101.10		92.00		50.73		32.8	++	848	56	0.413	3	219	21	603	0	5	Axinopsida serricata	574
																							Levinsenia gracilis	43
																							Nephtys cornuta	40
																							Aricidea (Acmira) lopezi	27
																							Parvilucina tenuisculpta	17
																							Cossura pygodactylata	12
																							Euphilomedes producta	11
																							Ampharete cf. crassiseta	10
																							Trochochaeta multisetosa	9
																							Mediomastus sp.	9
29, 194, Mid Elliott Bay	23	1.05	Dibenzo(a,h,) anthracene, Total PCBs	Mercury, Dibenzo(a,h) anthracene, 4-Methylphenol	Mercury, 4-Methylphenol	102.15		106.00		62.40		74.1	+++	456	46	0.539	4	184	10	261	0	1	Axinopsida serricata	247
																							Aricidea (Acmira) lopezi	38
																							Levinsenia gracilis	30
																							Spiophanes berkeleyorum	28
																							Prionospio (Minuspio) lighti	16
																							Scoletoma luti	13
																							Mediomastus sp.	6
																							Microclymene caudata	6
																							Macoma carlottensis	5
																							Cossura pygodactylata	5
29, 195, Mid Elliott Bay	12	0.54				105.38		90.00		61.87		49.3	+++	365	67	0.789	16	271	46	44	1	3	Levinsenia gracilis	76
																							Axinopsida serricata	36
																							Prionospio (Minuspio) lighti	24
																							Nephtys cornuta	20
																							Euphilomedes producta	18
																							Trochochaeta multisetosa	15
																							Aricidea (Acmira) lopezi	12
																							Euclymeninae	11
																							Cossura pygodactylata	10
																							Sigambra tentaculata	9

Appendix H. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
29, 196, Mid Elliott Bay	13	0.54	Mercury	Mercury	Mercury	100.00		108.00		55.63		28.6	++	471	42	0.451	3	131	18	320	2	0	Axinopsida serricata	310
																							Aricidea (Acmira) lopezi	29
																							Levinsenia gracilis	27
																							Prionospio (Minuspio) lighti	12
																							Scoletoma luti	11
																							Spiophanes berkeleyorum	8
																							Heterophoxus affinis	7
																							Cossura bansei	5
																							Nephtys ferruginea	4
																							Mediomastus sp.	4
30, 197, West Harbor Island	18	0.60	Arsenic, Zinc	Arsenic, Acenaphthene, Dibenzofuran, 4-Methylphenol	Arsenic, 4-Methylphenol	87.91		62.00	**	2.23		96.6	+++	806	71	0.679	12	394	103	304	1	4	Parvilucina tenuisculpta	261
																							Euphilomedes carcharodonta	89
																							Lumbrineris californiensis	64
																							Prionospio steenstrupi	47
																							Spiochaetopterus costarum	31
																							Aphelochaeta sp. N1	26
																							Mediomastus sp.	26
																							Magelona longicornis	15
																							Heteromastus filobranchus	15
																							Asabellides lineata	14
30, 198, West Harbor Island	22	1.26	2-Methylnaphthalene, Acenapththene, Fluorene, Napthalene, Total LPAHs, Total PCBs	Acenaphthene, Fluorene, Napthalene Total LPAHs, Dibenzofuran, 4-Methylphenol	Acenaphthene, Napthalene, Dibenzofuran, 4-Methylphenol	101.10		100.00		59.93		132.2	+++	1128	90	0.633	9	259	347	511	0	11	Axinopsida serricata	358
																							Euphilomedes carcharodonta	142
																							Euphilomedes producta	141
																							Parvilucina tenuisculpta	59
																							Rutiderma lomae	41
																							Myriochele heeri	40
																							Prionospio steenstrupi	34
																							Nemocardium centifilosum	26
																							Macoma carlottensis	14
																							Exogone (E.) lourei	14
30, 199, West Harbor Island	22	0.96	Total LPAHs, Total PCBs	Acenaphthene, Dibenzofuran, 4-Methylphenol	4-Methylphenol	90.11		73.00	**	64.80		148.1	+++	1391	84	0.653	10	473	406	495	11	6	Euphilomedes carcharodonta	357
																							Axinopsida serricata	212
																							Parvilucina tenuisculpta	154
																							Aphelochaeta sp. N1	130
																							Spiochaetopterus costarum	43
																							Scoletoma luti	43
																							Astyris gausapata	35
																							Magelona longicornis	35
																							Apistobranchus ornatus	34
																							Euphilomedes producta	33

Appendix H. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
30, 114, West	21	1.34	Benzo(a)pyrene, Total	Benzo(g,h,i) perylene	4-Methylphenol	94.95		86.00		0.79		111.4	+++	1077	47	0.386	2	982	21	73	0	1	Aphelochaeta sp. N1	763
Harbor Island			PCBs	4-Methylphenol																			Heteromastus filobranchus	60
																							Scoletoma luti	35
																							Cossura pygodactylata	35
																							Axinopsida serricata	23
																							Chaetozone nr. setosa	18
																							Parvilucina tenuisculpta	14
																							Aphelochaeta monilaris	13
																							Alvania compacta	13
																							Euphilomedes carcharodonta	11
31, 200, East	22	3.93	Total PCBs	1,4-Dichlorobenzene,	4-Methylphenol	100.00		68.00	**	25.40		153.5	+++	980	56	0.598	5	802	27	149	0	2	Aphelochaeta sp. N1	352
Harbor Island				4-Methylphenol																			Chaetozone nr. setosa	168
																							Axinopsida serricata	95
																							Scoletoma luti	86
																							Spiochaetopterus costarum	36
																							Prionospio steenstrupi	29
																							Heteromastus filobranchus	21
																							Parvilucina tenuisculpta	19
																							Euphilomedes carcharodonta	15
																							Lumbrineris californiensis	14
31, 201, East	23	1.60	Total PCBs	Bis(2-Ethylhexyl)	4-Methylphenol	92.31		66.00	**	3.13		135.3	+++	1415	57	0.386	2	1281	37	95	0	2	Aphelochaeta sp. N1	955
Harbor Island				Phthalate, 4-																			Scoletoma luti	140
				Methylphenol																			Axinopsida serricata	60
																							Aphelochaeta monilaris	44
																							Levinsenia gracilis	18
																							Spiochaetopterus costarum	15
																							Parvilucina tenuisculpta	13
																							Boccardiella hamata	12
																							Exogone (E.) lourei	12
																							Heteromastus filobranchus	10
31, 202, East	25	2.16	Total PCBs	4-Methylphenol	4-Methylphenol	90.11	*	100.00		7.67		133.2	+++	1572	42	0.446	3	891	23	657	0	1	Axinopsida serricata	589
Harbor Island																							Aphelochaeta sp. N1	514
																							Scoletoma luti	282
																							Aphelochaeta monilaris	22
																							Macoma sp.	18
																							Alvania compacta	17
																							Heteromastus filobranchus	13
																							Macoma carlottensis	13
																							Chaetozone nr. setosa	11
																							Prionospio steenstrupi	10

Appendix H. Continued.

Stratum, Sample, Location	Number of ERLs exceeded	Mean ERM Quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod Survival as % of Control	Significance	Mean Urchin Fertilization in 100% pore water as % of Control	Significance	Microtox EC50 (mg/ml)	Significance	Cytochrome P-450 RGS as ugB[a]P/g	Significance	Total Abundance	Taxa Richness	Evenness	Swartz's Dominance Index	Annelid Abundance	Arthropod Abundance	Mollusca Abundance	Echinoderm Abundance	Misc. Abundance	Dominant Species	Count
32, 203, Duwamish	13	0.67				103.30		98.00		3.20		96.9	+++	3764	94	0.426	3	2970	94	688	0	12	Aphelochaeta sp. N1	2152
																							Nutricola lordi	430
																							Scoletoma luti	320
																							Aphelochaeta sp.	91
																							Euphilomedes carcharodonta	68
																							Axinopsida serricata	65
																							Capitella capitata hyperspecies	62
																							Macoma sp.	58
																							Armandia brevis	47
																							Mediomastus sp.	41
32, 204, Duwamish	8	0.72	Total PCBs	Bis(2-Ethylhexyl) Phthalate, 4-Methylphenol	4-Methylphenol	92.31		103.00		3.33		77	+++	1155	52	0.373	2	1002	31	117	1	4	Aphelochaeta sp. N1	814
																							Scoletoma luti	58
																							Macoma sp.	47
																							Nutricola lordi	35
																							Capitella capitata hyperspecies	33
																							Euphilomedes carcharodonta	27
																							Armandia brevis	23
																							Euchone limnicola	14
																							Heteromastus filobranchus	13
																							Alvania compacta	11
32, 205, Duwamish	20	2.01	Total PCBs	Benzo(g,h,i) perylene, Indeno(1,2,3-c,d)pyrene, Butylbenzyl-phthalate, 4-Methylphenol, Penta-chlorophenol	4-Methylphenol	100.81		94.00		3.57		46.9	+++	1561	65	0.454	3	1314	17	226	1	3	Aphelochaeta sp. N1	660
																							Scoletoma luti	455
																							Nutricola lordi	98
																							Cossura pygodactylata	90
																							Axinopsida serricata	77
																							Macoma sp.	12
																							Macoma carlottensis	10
																							Lanassa venusta	9
																							Aphelochaeta sp.	8
																							Heteromastus filobranchus	8

Amphipod: * mean % survival significantly less than CLIS controls ($p<0.05$); ** mean % survival significantly less than CLIS controls ($p<0.05$) and less than 80% of CLIS controls

Urchin fertilization: * mean % fertilization significantly different from controls and exceeds minimum significant difference (Dunnett's t-test: * = $\alpha < 0.05$, MSD = 15.5%; or ** = $\alpha < 0.01$, MSD = 19.0%)

Microtox EC50: ^ = mean EC50<0.51 mg/ml determined as the 80% lower prediction limit (LPL) with the lowest (i.e., most toxic) samples removed, but >0.06 mg/ml determined as the 90% lower prediction limit (LPL) earlier in this report.

Cytochrome P450 HRGS as µgB[a]P/g: ++ = value >11.1 benzo[a]pyrene equivalents (ug/g sediment) determined as the 80% upper prediction limit (UPL); +++ = value >37.1 benzo[a]pyrene equivalents (µg/g sediment) determined as the 90% upper prediction limit (UPL)

Appendix I

Ranges in detected chemical concentrations and numbers of samples for national, SEDQUAL, and 1998 PSAMP/NOAA central Puget Sound data.

Appendix I. Ranges in detected chemical concentrations and numbers of samples for national, SEDQUAL and 1998 PSAMP/NOAA central Puget Sound data.

		Range in National Data[1]				Range in SEDQUAL Data[2]				Range in PSAMP/NOAA Data[3]			
Chemical	Units	No. of Samples	Min	Median	Max	No. of Samples	Min	Median	Max	No. of Samples	Min	Median	Max
Amines and Aromatic amines													
1,2-Diphenylhydrazine	ppb	n/a	n/a	n/a	n/a	2	0.0	3.5	7.0	n/a	n/a	n/a	n/a
Aniline	ppb	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Benzidine	ppb	n/a	n/a	n/a	n/a	1	15,000.0	15,000.0	15,000.0	n/a	n/a	n/a	n/a
N-nitrosodimethylamine	ppb	n/a	n/a	n/a	n/a	1	1,000.0	1,000.0	1,000.0	n/a	n/a	n/a	n/a
Pyridine	ppb	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Chlorinated Alkanes													
Hexachlorobutadiene	ppb	n/a	n/a	n/a	n/a	41	0.0	5.0	1,200.0	0	0.0	0.0	0.0
Hexachlorocyclopentadiene	ppb	n/a	n/a	n/a	n/a	4	40.0	160.0	230.0	n/a	n/a	n/a	n/a
Hexachloroethane	ppb	n/a	n/a	n/a	n/a	4	47.0	160.0	230.0	n/a	n/a	n/a	n/a
Chlorinated and Nitro-Substituted Phenols													
2,4,5-Trichlorophenol	ppb	n/a	n/a	n/a	n/a	6	370.0	1,100.0	6,900.0	n/a	n/a	n/a	n/a
2,4,6-Trichlorophenol	ppb	n/a	n/a	n/a	n/a	6	150.0	250.0	2,800.0	n/a	n/a	n/a	n/a
2,4-Dichlorophenol	ppb	n/a	n/a	n/a	n/a	2	220.0	225.0	230.0	n/a	n/a	n/a	n/a
2,4-Dinitrophenol	ppb	n/a	n/a	n/a	n/a	3	1,100.0	5,000.0	9,530.0	n/a	n/a	n/a	n/a
2-Chlorophenol	ppb	n/a	n/a	n/a	n/a	6	1.0	141.0	540.0	n/a	n/a	n/a	n/a
2-Nitrophenol	ppb	n/a	n/a	n/a	n/a	6	3.0	98.5	230.0	n/a	n/a	n/a	n/a
4,6-Dinitro-2-Methylphenol	ppb	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
4-Chloro-3-Methylphenol	ppb	n/a	n/a	n/a	n/a	12	1.0	124.0	1,200.0	n/a	n/a	n/a	n/a
4-Nitrophenol	ppb	n/a	n/a	n/a	n/a	2	90.0	595.0	1,100.0	n/a	n/a	n/a	n/a
Pentachlorophenol	ppb	n/a	n/a	n/a	n/a	56	1.0	97.5	41,000.0	23	98.00	159.00	527.00
Chlorinated Aromatic Compounds													
1,2,4-Trichlorobenzene	ppb	n/a	n/a	n/a	n/a	46	1.0	7.0	305.0	2	0.77	3.58	6.40

Appendix I. Continued.

		Range in National Data[1]				Range in SEDQUAL Data[2]				Range in PSAMP/NOAA Data[3]			
Chemical	Units	No. of Samples	Min	Median	Max	No. of Samples	Min	Median	Max	No. of Samples	Min	Median	Max
1,2-Dichlorobenzene	ppb	n/a	n/a	n/a	n/a	76	0.0	3.0	963.0	5	0.35	1.30	6.40
1,3-Dichlorobenzene	ppb	n/a	n/a	n/a	n/a	47	1.0	4.0	230.0	3	0.83	1.80	17.00
1,4-Dichlorobenzene	ppb	n/a	n/a	n/a	n/a	216	0.0	12.0	31,000.0	40	0.34	3.60	79.00
2-Chloronaphthalene	ppb	n/a	n/a	n/a	n/a	7	150.0	230.0	2,800.0	0	0.00	0.00	0.00
Hexachlorobenzene	ppb	n/a	n/a	n/a	n/a	48	0.0	2.0	15,000.0	29	0.10	0.34	4.50
Ethers													
4-Bromophenyl-Phenyl Ether	ppb	n/a	n/a	n/a	n/a	6	130.0	225.0	15,000.0	n/a	n/a	n/a	n/a
4-Chlorophenyl-Phenyl Ether	ppb	n/a	n/a	n/a	n/a	3	3.0	220.0	230.0	n/a	n/a	n/a	n/a
Bis(2-Chloroethyl)Ether	ppb	n/a	n/a	n/a	n/a	3	75.0	220.0	230.0	n/a	n/a	n/a	n/a
Bis(2-chloroisopropyl)-ether	ppb	n/a	n/a	n/a	n/a	2	220.0	225.0	230.0	n/a	n/a	n/a	n/a
Mixcellaneous Extractable Compounds													
Benzoic acid	ppb	n/a	n/a	n/a	n/a	214	5.0	290.0	58,394.0	95	607.00	2,290.00	13,000.00
Benzyl alcohol	ppb	n/a	n/a	n/a	n/a	25	5.0	140.0	8,800.0	26	21.00	34.00	75.00
Beta-coprostanol	ppb	n/a	n/a	n/a	n/a	221	26.0	497.0	69,851.0	n/a	n/a	n/a	n/a
Dibenzofuran	ppb	n/a	n/a	n/a	n/a	622	2.0	50.0	190,000.0	99	1.10	14.00	2,010.00
Isophorone	ppb	n/a	n/a	n/a	n/a	17	19.0	65.0	960.0	n/a	n/a	n/a	n/a
Organonitrogen Compounds													
2,4-Dinitrotoluene	ppb	n/a	n/a	n/a	n/a	4	220.0	420.0	15,000.0	n/a	n/a	n/a	n/a
2,6-Dinitrotoluene	ppb	n/a	n/a	n/a	n/a	5	220.0	290.0	1,900.0	n/a	n/a	n/a	n/a
2-Nitroaniline	ppb	n/a	n/a	n/a	n/a	6	90.0	890.0	6,900.0	n/a	n/a	n/a	n/a
3,3'-Dichlorobenzidine	ppb	n/a	n/a	n/a	n/a	5	90.0	440.0	1,900.0	n/a	n/a	n/a	n/a
3-Nitroaniline	ppb	n/a	n/a	n/a	n/a	4	90.0	680.0	1,100.0	n/a	n/a	n/a	n/a
4-Chloroaniline	ppb	n/a	n/a	n/a	n/a	6	125.0	225.0	1,212.0	n/a	n/a	n/a	n/a
4-Nitroaniline	ppb	n/a	n/a	n/a	n/a	3	90.0	1,100.0	1,100.0	n/a	n/a	n/a	n/a

Appendix I. Continued.

Chemical	Units	Range in National Data[1]				Range in SEDQUAL Data[2]				Range in PSAMP/NOAA Data[3]			
		No. of Samples	Min	Median	Max	No. of Samples	Min	Median	Max	No. of Samples	Min	Median	Max
9(H)Carbazole	ppb	n/a	n/a	n/a	n/a	505	2.0	74.0	52,000.0	n/a	n/a	n/a	n/a
Caffeine	ppb	n/a	n/a	n/a	n/a	3	2.0	9.0	130.0	n/a	n/a	n/a	n/a
Nitrobenzene	ppb	n/a	n/a	n/a	n/a	2	220.0	225.0	230.0	n/a	n/a	n/a	n/a
N-Nitroso-Di-N-Propylamine	ppb	n/a	n/a	n/a	n/a	4	190.0	225.0	280.0	n/a	n/a	n/a	n/a
N-nitrosodiphenylamine	ppb	n/a	n/a	n/a	n/a	43	6.0	130.0	15,000.0	5	5.70	14.00	34.00
Phenols													
2,4-Dimethylphenol	ppb	n/a	n/a	n/a	n/a	44	1.0	67.5	6,000.0	19	4.30	12.00	35.00
2-Methylphenol	ppb	n/a	n/a	n/a	n/a	19	1.0	140.0	1,722.0	67	1.20	6.40	48.00
4-Methylphenol	ppb	n/a	n/a	n/a	n/a	144	1.0	61.5	6,208.0	97	2.20	31.00	6,250.00
Bis(2-Chloroethoxy)Methane	ppb	n/a	n/a	n/a	n/a	2	220.0	225.0	230.0	n/a	n/a	n/a	n/a
Phenol	ppb	n/a	n/a	n/a	n/a	490	0.0	80.0	3,600.0	40	44.00	109.00	1,730.00
P-nonylphenol	ppb	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2	18.00	19.50	21.00
Phthalate Esters													
Bis(2-Ethylhexyl) Phthalate	ppb	n/a	n/a	n/a	n/a	993	0.0	349.0	63,000.0	16	139.00	460.00	1,030.00
Butylbenzylphthalate	ppb	n/a	n/a	n/a	n/a	559	0.0	50.0	5,500.0	20	7.70	47.00	92.00
Diethylphthalate	ppb	n/a	n/a	n/a	n/a	128	1.0	16.0	15,000.0	21	3.50	25.00	151.00
Dimethylphthalate	ppb	n/a	n/a	n/a	n/a	197	0.0	25.0	11,000.0	12	3.30	11.10	65.00
Di-N-Butylphthalate	ppb	n/a	n/a	n/a	n/a	418	0.0	52.0	7,400.0	30	70.00	364.00	2,890.00
Di-N-Octyl Phthalate	ppb	n/a	n/a	n/a	n/a	233	0.0	71.0	68,602.0	1	16.00	16.00	16.00
Organotin, Butyl tin													
Dibutyltin Chloride	ppb	n/a	n/a	n/a	n/a	1	82.0	82.0	82.0	67	0.74	15.00	170.00
Monobutyltin Chloride	ppb	n/a	n/a	n/a	n/a	49	0.0	10.0	1,060.0	n/a	n/a	n/a	n/a
Tributyltin Chloride	ppb	n/a	n/a	n/a	n/a	15	1.0	9.0	198.0	86	0.49	17.15	3,110.00
Ancillary Metals (Partial Digestion Method)													
Aluminum	ppm	n/a	n/a	n/a	n/a	1,216	0.0	18,450.0	48,100.0	105	5,280.00	11,200.00	21,000.00

Appendix I. Continued.

Chemical	Units	Range in National Data[1]				Range in SEDQUAL Data[2]				Range in PSAMP/NOAA Data[3]			
		No. of Samples	Min	Median	Max	No. of Samples	Min	Median	Max	No. of Samples	Min	Median	Max
Barium	ppm	n/a	n/a	n/a	n/a	855	0.0	66.0	7,380.0	105	7.80	33.00	119.00
Calcium	ppm	n/a	n/a	n/a	n/a	821	1,740.0	6,820.0	347,000.0	105	2,540.00	5,040.00	15,200.00
Cobalt	ppm	n/a	n/a	n/a	n/a	518	2.0	10.0	119.0	105	2.80	6.93	15.40
Iron	ppm	n/a	n/a	n/a	n/a	1,272	1.0	26,250.0	112,000.0	105	7,160.00	19,600.00	30,400.00
Magnesium	ppm	n/a	n/a	n/a	n/a	879	1,957.0	7,950.0	1,100,000.0	105	3,360.00	7,020.00	12,200.00
Manganese	ppm	n/a	n/a	n/a	n/a	1,172	0.0	308.5	3,390.0	105	107.00	237.00	1,010.00
Potassium	ppm	n/a	n/a	n/a	n/a	795	380.0	2,670.0	373,000.0	105	630.00	1,690.00	4,000.00
Sodium	ppm	n/a	n/a	n/a	n/a	784	800.0	11,100.0	973,000.0	105	3,000.00	9,220.00	30,300.00
Vanadium	ppm	n/a	n/a	n/a	n/a	622	11.0	58.0	146.0	105	16.10	41.40	63.90
Ancillary Metals (Total Digestion Method)													
Aluminum	ppm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	104	18,000.00	67,400.00	91,600.00
Barium	ppm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	104	212.00	389.00	576.00
Calcium	ppm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	104	7,070.00	19,100.00	36,800.00
Cobalt	ppm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	104	4.20	10.00	24.90
Iron	ppm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	104	14,400.00	32,350.00	56,400.00
Magnesium	ppm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	104	2,540.00	12,700.00	18,300.00
Manganese	ppm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	104	296.00	494.00	1,370.00
Potassium	ppm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	104	7,040.00	10,900.00	17,100.00
Sodium	ppm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	104	21,200.00	29,300.00	45,900.00
Vanadium	ppm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	104	50.20	93.85	122.00
Priority Pollutant Metals (Partial Digestion Method)													
Antimony	ppm	n/a	n/a	n/a	n/a	791	0.0	2.0	1,370.0	39	0.20	0.37	110.00
Arsenic	ppm	n/a	n/a	n/a	n/a	1,953	0.0	11.0	1,420.0	105	1.60	6.49	500.00
Beryllium	ppm	n/a	n/a	n/a	n/a	968	0.0	0.0	4.0	101	0.10	0.26	0.48
Cadmium	ppm	n/a	n/a	n/a	n/a	1,733	0.0	0.0	100.0	94	0.10	0.30	1.72
Chromium	ppm	n/a	n/a	n/a	n/a	1,942	0.0	39.0	1,093.0	105	11.30	29.20	79.40
Copper	ppm	n/a	n/a	n/a	n/a	2,283	0.0	54.0	2,820.0	105	4.00	30.00	330.00
Lead	ppm	n/a	n/a	n/a	n/a	2,261	0.0	42.0	71,100.0	105	2.64	21.80	500.00

Appendix I. Continued.

Chemical	Units	Range in National Data[1]				Range in SEDQUAL Data[2]				Range in PSAMP/NOAA Data[3]			
		No. of Samples	Min	Median	Max	No. of Samples	Min	Median	Max	No. of Samples	Min	Median	Max
Mercury	ppm	n/a	n/a	n/a	n/a	2,018	0.0	0.0	28.0	105	0.01	0.13	1.50
Nickel	ppm	n/a	n/a	n/a	n/a	2,179	1.0	29.0	366.0	105	11.00	27.60	41.70
Selenium	ppm	n/a	n/a	n/a	n/a	536	0.0	0.0	63.0	52	0.31	0.58	0.96
Silver	ppm	n/a	n/a	n/a	n/a	1,399	0.0	0.0	140.0	93	0.10	0.39	2.01
Thallium	ppm	n/a	n/a	n/a	n/a	428	0.0	0.0	21.0	100	0.11	0.20	1.79
Titanium	ppm	n/a	n/a	n/a	n/a	21	400.0	1,000.0	1,200.0	105	279.00	689.00	1,160.00
Zinc	ppm	n/a	n/a	n/a	n/a	2,263	0.0	104.0	7,390.0	105	19.10	63.90	1,290.00
Priority Pollutant Metals (Total Digestion Method)													
Antimony	ppm	n/a	n/a	n/a	n/a	52	0.0	2.0	36.0	85	0.30	1.00	356.00
Arsenic	ppm	913	0.10	7.10	41.00	74	1.0	11.0	38.0	104	1.90	7.77	555.00
Beryllium	ppm	n/a	n/a	n/a	n/a	2	0.0	0.0	0.0	104	0.60	0.96	1.40
Cadmium	ppm	987	0.03	0.30	19.80	59	0.0	1.0	3.0	75	0.11	0.80	2.00
Chromium	ppm	1,045	1.00	57.80	1,220.00	37	12.0	79.0	110.0	104	36.70	72.30	203.00
Copper	ppm	1,031	0.70	20.70	1,770.00	93	4.0	78.0	1,240.0	104	4.90	31.55	290.00
Lead	ppm	1,038	1.40	26.30	510.00	84	4.0	65.0	659.0	104	6.60	21.00	388.00
Mercury	ppm	994	0.01	0.10	15.00	26	0.0	0.0	0.0	105	0.01	0.13	1.50
Nickel	ppm	1,006	0.30	21.00	136.00	54	14.0	38.0	117.0	104	17.00	37.00	55.00
Selenium	ppm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	64	0.31	0.56	1.10
Silver	ppm	866	0.01	0.20	10.10	70	0.0	0.0	4.0	4	1.20	1.45	1.80
Thallium	ppm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	58	0.21	0.31	0.62
Titanium	ppm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	104	1,670.00	3,420.00	5,090.00
Zinc	ppm	1,060	1.00	93.30	1,880.00	93	13.0	141.0	654.0	104	29.60	91.20	1,450.00
HPAH													
Benzo(a)anthracene	ppb	652	0.30	96.20	59,298.00	1,532	0.0	280.0	913,500.0	105	1.50	72.00	1,760.00
Benzo(a)pyrene	ppb	631	0.20	147.00	54,862.00	1,628	0.0	300.0	1,035,300.0	105	1.30	99.00	2,910.00
Benzo(b)fluoranthene	ppb	n/a	n/a	n/a	n/a	1,052	0.0	510.0	913,500.0	105	2.60	157.00	6,670.00
Benzo(e)pyrene	ppb	n/a	n/a	n/a	n/a	1	3,500.0	3,500.0	3,500.0	105	1.50	78.50	1,280.00
Benzo(g,h,i)perylene	ppb	n/a	n/a	n/a	n/a	1,323	0.0	170.0	475,070.0	105	1.40	83.00	1,000.00
Benzo(k)fluoranthene	ppb	n/a	n/a	n/a	n/a	997	0.0	380.0	669,900.0	105	0.59	59.00	2,360.00

Appendix I. Continued.

Chemical	Units	Range in National Data[1]				Range in SEDQUAL Data[2]				Range in PSAMP/NOAA Data[3]			
		No. of Samples	Min	Median	Max	No. of Samples	Min	Median	Max	No. of Samples	Min	Median	Max
Chrysene	ppb	688	0.20	118.00	60,331.00	1,713	0.0	387.0	913,500.0	105	2.60	118.00	1,710.00
Dibenzo(a,h)anthracene	ppb	363	0.40	45.80	4,534.00	758	0.0	69.5	140,070.0	102	0.48	17.00	392.00
Fluoranthene	ppb	755	0.30	160.00	108,236.00	1,820	0.0	500.0	1,827,000.0	105	4.90	182.00	43,000.00
Indeno(1,2,3-c,d)pyrene	ppb	n/a	n/a	n/a	n/a	1,364	0.0	180.0	444,570.0	105	1.20	86.00	1,220.00
Perylene	ppb	n/a	n/a	n/a	n/a	82	5.0	24.0	510.0	105	4.20	104.00	949.00
Pyrene	ppb	819	0.40	136.00	143,132.00	1,812	0.0	580.0	2,618,700.0	105	4.50	206.00	14,400.00
Total HPAH	ppb	925	2.00	405.00	461,675.00	1,544	2.0	3,020.0	9,920,000.0	105	30.73	1,239.50	75,951.00
Total Benzofluoranthenes	ppb	n/a	n/a	n/a	n/a	1,394	1.0	740.0	1,582,000.0	105	3.19	201.50	9,030.00
LPAH													
1,6,7-Trimethylnaphthalene	ppb	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	102	0.99	17.00	136.00
1-Methylnaphthalene	ppb	n/a	n/a	n/a	n/a	1	790.0	790.0	790.0	99	0.92	17.00	728.00
1-Methylphenanthrene	ppb	n/a	n/a	n/a	n/a	63	2.0	130.0	100,000.0	100	1.20	27.00	195.00
2,6-Dimethylnaphthalene	ppb	n/a	n/a	n/a	n/a	1	570.0	570.0	570.0	103	1.10	37.00	272.00
2-Methylnaphthalene	ppb	591	0.40	22.10	15,557.00	522	0.0	37.0	200,000.0	99	1.40	29.00	1,030.00
2-Methylphenanthrene	ppb	n/a	n/a	n/a	n/a	64	2.0	125.0	110,000.0	102	2.20	38.00	312.00
Acenaphthene	ppb	394	0.10	25.70	56,338.00	887	0.0	57.0	280,140.0	93	0.48	7.30	1,670.00
Acenaphthylene	ppb	254	0.40	45.40	12,915.00	603	0.0	40.0	66,990.0	104	0.05	15.00	193.00
Anthracene	ppb	521	0.20	63.90	89,366.00	1,443	0.0	130.0	578,550.0	105	0.97	32.00	1,120.00
Biphenyl	ppb	n/a	n/a	n/a	n/a	43	2.0	30.0	1,800.0	94	0.44	9.00	387.00
Dibenzothiophene	ppb	n/a	n/a	n/a	n/a	49	0.0	80.0	29,000.0	89	1.00	9.20	334.00
Fluorene	ppb	530	0.10	28.70	54,209.00	1,091	0.0	66.0	230,000.0	102	0.76	17.00	830.00
Naphthalene	ppb	456	0.70	39.50	17,414.00	761	0.0	51.0	1,100,000.0	96	1.90	38.00	8,370.00
Phenanthrene	ppb	779	0.40	75.00	194,343.00	1,679	0.0	260.0	1,583,400.0	102	3.30	93.50	3,830.00
Retene	ppb	n/a	n/a	n/a	n/a	183	2.0	58.0	10,000.0	103	1.90	46.00	1,320.00
Total LPAH	ppb	956	0.20	118.00	552,124.00	1,573	0.0	460.0	2,810,000.0	105	19.39	469.80	15,036.00
Chlorinated Pesticides													
2,4'-DDD	ppb	n/a	n/a	n/a	n/a	1	15.0	15.0	15.0	0	0.00	0.00	0.00
2,4'-DDE	ppb	n/a	n/a	n/a	n/a	1	4.0	4.0	4.0	0	0.00	0.00	0.00
2,4'-DDT	ppb	n/a	n/a	n/a	n/a	1	6.0	6.0	6.0	0	0.00	0.00	0.00
4,4'-DDD	ppb	666	0.00	1.40	784.00	164	0.0	6.0	840.0	36	0.80	3.15	14.00

Appendix I. Continued.

Chemical	Units	Range in National Data[1]				Range in SEDQUAL Data[2]				Range in PSAMP/NOAA Data[3]			
		No. of Samples	Min	Median	Max	No. of Samples	Min	Median	Max	No. of Samples	Min	Median	Max
4,4'-DDE	ppb	741	0.00	2.00	2,900.00	172	0.0	3.0	370.0	44	0.21	2.20	12.00
4,4'-DDT	ppb	543	0.00	1.00	3,517.00	82	0.0	9.5	1,670.0	4	3.00	3.45	5.00
Total DDTs	ppb	813	0.01	4.30	4,631.00	725	0.0	8.0	3,100.0	42	0.21	4.45	20.60
Aldrin	ppb	n/a	n/a	n/a	n/a	40	0.0	2.0	90.0	0	0.00	0.00	0.00
Alpha-BHC	ppb	n/a	n/a	n/a	n/a	2	0.0	50.0	100.0	0	0.00	0.00	0.00
Alpha-chlordane	ppb	n/a	n/a	n/a	n/a	5	1.0	1.0	26.0	2	0.59	1.00	1.40
Beta-BHC	ppb	n/a	n/a	n/a	n/a	1	13.0	13.0	13.0	0	0.00	0.00	0.00
Chlorpyriphos	ppb	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	0.00	0.00	0.00
Cis-Nonachlor	ppb	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	0.00	0.00	0.00
Delta-BHC	ppb	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	0.00	0.00	0.00
Dieldrin	ppb	490	0.00	0.50	21.20	43	0.0	2.0	280.0	0	0.00	0.00	0.00
Endosulfan I	ppb	n/a	n/a	n/a	n/a	4	0.0	1.5	17.0	0	0.00	0.00	0.00
Endosulfan II	ppb	n/a	n/a	n/a	n/a	2	3.0	3.5	4.0	0	0.00	0.00	0.00
Endosulfan sulfate	ppb	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	0.00	0.00	0.00
Endrin	ppb	n/a	n/a	n/a	n/a	4	3.0	6.0	10.0	0	0.00	0.00	0.00
Endrin Aldehyde	ppb	n/a	n/a	n/a	n/a	8	3.0	5.0	130.0	0	0.00	0.00	0.00
Endrin Ketone	ppb	n/a	n/a	n/a	n/a	1	42.0	42.0	42.0	0	0.00	0.00	0.00
Gamma-BHC (Lindane)	ppb	306	0.01	0.20	157.00	9	0.0	0.0	8.0	2	0.57	1.34	2.10
Heptachlor	ppb	n/a	n/a	n/a	n/a	19	0.0	2.0	28.0	2	0.71	2.41	4.10
Heptachlor Epoxide	ppb	n/a	n/a	n/a	n/a	9	0.0	3.0	13.0	0	0.00	0.00	0.00
Methoxychlor	ppb	n/a	n/a	n/a	n/a	3	2.0	2.0	99.0	1	10.00	10.00	10.00
Mirex	ppb	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	0.00	0.00	0.00
Oxychlordane	ppb	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	0.00	0.00	0.00
Toxaphene	ppb	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	0.00	0.00	0.00
Trans-Chlordane (Gamma)	ppb	n/a	n/a	n/a	n/a	1	204.0	204.0	204.0	1	0.58	0.58	0.58
Trans-Nonachlor	ppb	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Polycyclic Chlorinated Biphenyls													
PCB Arochlor 1016	ppb	n/a	n/a	n/a	n/a	7	100.0	100.0	100.0	0	0.00	0.00	0.00
PCB Arochlor 1221	ppb	n/a	n/a	n/a	n/a	5	28.0	51.0	200.0	0	0.00	0.00	0.00
PCB Arochlor 1232	ppb	n/a	n/a	n/a	n/a	1	300.0	300.0	300.0	0	0.00	0.00	0.00

Appendix I. Continued.

		Range in National Data[1]				Range in SEDQUAL Data[2]				Range in PSAMP/NOAA Data[3]			
Chemical	Units	No. of Samples	Min	Median	Max	No. of Samples	Min	Median	Max	No. of Samples	Min	Median	Max
PCB Arochlor 1242	ppb	n/a	n/a	n/a	n/a	136	1.0	51.0	2,500.0	7	4.20	12.00	50.00
PCB Arochlor 1248	ppb	n/a	n/a	n/a	n/a	238	1.0	120.0	56,475.0	0	0.00	0.00	0.00
PCB Arochlor 1254	ppb	n/a	n/a	n/a	n/a	797	3.0	86.0	14,448.0	54	2.50	30.50	300.00
PCB Arochlor 1260	ppb	n/a	n/a	n/a	n/a	756	2.0	85.0	28,450.0	63	2.70	39.00	2,000.00
PCB Congener 8	ppb	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	7	0.25	0.62	1.70
PCB Congener 18	ppb	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	33	0.21	0.84	6.80
PCB Congener 28	ppb	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	47	0.09	1.30	24.00
PCB Congener 44	ppb	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	52	0.24	0.98	8.80
PCB Congener 52	ppb	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	63	0.12	1.50	22.00
PCB Congener 66	ppb	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	63	0.10	1.20	24.00
PCB Congener 77	ppb	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1	7.50	7.50	7.50
PCB Congener 101	ppb	n/a	n/a	n/a	n/a	206	1.0	5.0	310.0	71	0.07	2.40	76.00
PCB Congener 105	ppb	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	59	0.13	2.20	35.00
PCB Congener 118	ppb	n/a	n/a	n/a	n/a	214	1.0	5.0	280.0	72	0.10	2.55	29.00
PCB Congener 126	ppb	n/a	n/a	n/a	n/a	11	1.0	2.0	4.0	1	1.40	1.40	1.40
PCB Congener 128	ppb	n/a	n/a	n/a	n/a	137	1.0	2.0	71.0	61	0.07	1.10	14.00
PCB Congener 138	ppb	n/a	n/a	n/a	n/a	194	2.0	10.0	400.0	65	0.23	4.60	140.00
PCB Congener 153	ppb	n/a	n/a	n/a	n/a	212	1.0	8.0	260.0	79	0.11	2.90	210.00
PCB Congener 170	ppb	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	63	0.07	1.90	110.00
PCB Congener 180	ppb	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	65	0.11	2.60	190.00
PCB Congener 187	ppb	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	52	0.18	2.60	100.00
PCB Congener 195	ppb	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	37	0.12	0.61	18.00
PCB Congener 206	ppb	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	56	0.08	0.80	8.70
PCB Congener 209	ppb	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	43	0.20	0.85	3.00
Total PCB's	ppb	830	0.10	26.50	16,675.00	986	0.0	180.5	84,000.0	77	0.40	34.72	1,866.60

[1]Studies performed by the National Oceanic and Atmospheric Administration (NOAA) and U.S Environmental Protection Agency (Long et. al., 1998)

[2]Studies performed in Washington State and stored by Washington State Dept. of Ecology in the SEDQUAL database.

[3]Data collected in Central Puget Sound by the National Oceanic and Atmospheric Administration (NOAA) and the Washington State Dept. of Ecology.

Appendix J

SEDQUAL surveys for the 1998 central Puget Sound sampling area.

Appendix J. SEDQUAL surveys for the 1998 central Puget Sound sampling area.

Agency Name	Survey Name	Beginning date	Ending date	Chief Scientist
Beak Consultants, Inc.	U.S. Navy Pier D Long-Term Area Monitor	12/17/1994	03/07/1995	
	'98 Bremerton WTP NPDES Sed. Mon. Report	04/28/1998	04/29/1998	Gerald M. Erickson
Bremerton-Kitsap Co. Health District	Sinclair and Dyes Inlet monitoring 91-92	02/12/1991	06/04/1992	K. Grellner, R.S.
Chevron Oil USA, Inc.	Chevron USA Edmonds Dock Maint. Dredging	01/31/1990	01/31/1990	D. Kendall (Corps)
City of Seattle/WA Dept of Ecology	South Lake Union Pilot Project Sediment	12/01/1986	12/01/1986	
COE	Morton Marine maintenance dredging	09/15/1991	09/18/1991	D. Kendall (Corps)
Corps	Morton wharf construct. & draft increase	12/12/1989	12/12/1989	D. Kendall (Corps)
Department of Ecology/Port Townsend Paper Co.	Pt. Townsend Paper Company Class 2	12/01/1987	12/01/1987	D. Reif/D. Kjosnes
Dept of Oceanography, UW	Metals in Puget Sound sediments 1970-72	01/01/1972	01/01/1972	Eric A. Crecelius
Ecology/Environ. Invest. & Lab. Services	Bioaccum. study in Sinclair/Dyes Inlets	09/02/1989	01/15/1991	Jim Cubbage
	Salmon Bay Phase II	06/26/1996	06/27/1996	Darve Serdar
ECO CHEM	Seattle City Light, 11/89	05/24/1989	05/24/1989	R. Robert Zisette
EPA Region 10/Puget Sound Estuary Prog.	Port Townsend & Cap Sante Marinas Study	06/16/1988	06/28/1988	E. Crecelius
EPA, Dept. of Social & Health Services	Dept. of Health shellfish bioaccum study	04/24/1986	08/11/1987	Jacques Faigenblum

Appendix J. Continued.

Agency Name	Survey Name	Beginning date	Ending date	Chief Scientist
Geo Engineers, Inc.	U.S. Navy Pier D Supplemental Sampling	08/10/1993	08/13/1993	Sally Fisher
HartCrowser, Inc.	So. Lake Union Park -Kurtzer Marine Park	08/26/1990	09/03/1990	John Funderburk
Hurlen Construction Co., Seattle	Hurlen Construction Co. Maint. Dredging.	05/11/1990	05/11/1990	D. Kendall (Corps)
King County	Richmond Beach IT Monitoring 1994-96	07/18/1994	07/29/1996	John Blaine
	Lake Union Sediment Monitoring 81-86.	03/17/1981	11/10/1986	Fritz Grothkopp
	NPDES Connecticut CSO Baseline Study	06/01/1995	06/01/1995	Scott Mickelson
	NPDES Hanford CSO Baseline Study, 1995	06/01/1995	06/01/1995	Scott Mikelson
	Lake Union Sediment Monitoring 1995	07/26/1995	07/27/1995	Jeff Droker
	Duwamish/Diagonal Cleanup Phases 1 - 2	08/01/1994	07/01/1996	Scott Mickelson
	Pier 53 Cap Monitoring 1996	08/12/1996	08/15/1996	Ben Budka
	Denny Way Cap Monitoring 1994-96	06/15/1994	09/10/1996	Wilson and Romberg
	NPDES Chelan CSO Baseline Study, 1995-96	06/01/1995	09/25/1996	Scott Mickelson
	West Point EBO Baseline Study Phase 1	02/01/1996	09/25/1996	Scott Mickelson
	NPDES Magnolia CSO Baseline Study, 1996	10/01/1996	10/01/1996	John Blaine
	Magnolia, North Beach, 53rd Street CSO's	10/15/1996	10/15/1996	Scott Mickelson
	King County's NPDES CSO Subtidal Sed	10/16/1996	10/16/1996	
	Duwamish River Water Quality Assessment	02/01/1997	06/01/1997	Scott Mickelson
	West Point Subtidal NPDES Monit. 1994-97	04/25/1994	07/22/1997	John Blaine
	NPDES 63rd Ave CSO Baseline Study, 1997	10/01/1997	10/01/1997	John Blaine
	NPDES Barton CSO Baseline Study	10/01/1997	10/01/1997	Colin Elliott
	University Regulator Post CSO Separat'n	08/26/1996	10/03/1997	Fritz Grothkopp
	NPDES Renton Subtidal Monitoring 1994-97	09/20/1994	10/13/1997	John Blaine
	NPDES Alaska CSO Baseline Study	10/14/1997	10/14/1997	John Blaine
	NPDES CSO Subtidal sediments, 1997	10/14/1997	10/15/1997	
	Ambient Subtidal Monitoring 1994-1997	09/28/1994	10/16/1997	John Blaine

Appendix J. Continued.

Agency Name	Survey Name	Beginning date	Ending date	Chief Scientist
Lake Union Drydock Co./ Hart-Crowser	Lake Union Drydock Sediment Monitoring	05/19/1992	05/19/1992	Hart-Crowswer
Lonestar NorthWest	Lonestar NW, maint. dredge Duwamish Riv.	09/14/1989	09/14/1989	D. Kendall (Corps)
Metropolitan Seattle	TPPS Phase III A & B	03/04/1981	10/01/1982	
	TPPS Preliminary survey	04/21/1981	10/27/1982	
	1984 Duwamish Head Survey	01/01/1984	01/01/1984	
	Gamponia survey of Elliott Bay	01/07/1985	02/04/1985	
	Duwamish Head Baseline Survey, '85-'86	07/24/1985	07/17/1986	
	METRO's Hot Spot Invest. Waterfront, '88	05/10/1988	05/25/1988	Pat Romberg
	Pier 53/55 METRO's Monitoring Report,'88	05/25/1988	05/25/1988	Pat Romberg
	METRO's Hot Spot Invest. Denny Way, 88	06/29/1988	06/29/1988	Pat Romberg
	METRO's Hot Spot Invest. 4 Mile Rock, 89	06/20/1989	06/20/1989	Pat Romberg
	METRO's Hot Spot Invest. Waterfront, '89	06/19/1989	08/17/1989	Pat Romberg
	Pier 53/55 METRO's Monitoring Report,'89	06/19/1989	08/17/1989	Pat Romberg
	WestPoint emergency bypass outfall.	10/13/1989	10/24/1989	D. Kendall (Corps)
	DUWAMISH CSO Sediment Sampling in 1990	05/23/1990	05/24/1990	Pat Romberg
	METRO'S Renton Sed. Monitoring, 1990	03/29/1990	08/02/1990	Pat Romberg
	METRO's Hot Spot Invest. Waterfront, '90	10/24/1990	10/24/1990	Pat Romberg
	METRO Hot Spot Invest. West Seattle, '90	09/20/1990	10/24/1990	Pat Romberg
	METRO's Hot Spot Denny Way Subtidal, '92	07/01/1992	07/01/1992	Pat Romberg
	METRO'S Intertidal Survey, 1992	08/24/1992	08/26/1992	Pat Romberg
	METRO'S Puget Sound Ambient Monitorg,'92	09/15/1992	10/12/1992	Pat Romberg
	METRO'S Renton Sediment Monitoring, '92	09/10/1992	10/12/1992	Pat Romberg
	METRO'S Duwamish CSO sed. sampling, 1992	10/28/1992	10/30/1992	Pat Romberg
	Pier 53-55 Sed Cap & ENR Remed Project	02/26/1992	11/24/1992	Pat Romberg
	Metro QA Review of P53-55 Capping Data	05/18/1993	05/21/1993	Metro

Appendix J. Continued.

Agency Name	Survey Name	Beginning date	Ending date	Chief Scientist
National Oceanic and Atmospheric Admin.	1980 NOAA OMPA-19 survey of Elliott Bay.	01/01/1979	09/01/1980	
	Eagle Harb. English sole accum. & histo.	11/29/1983	04/05/1984	Donald Malins
	NOAA Nat'l Status & Trends mussel watch	01/07/1986	03/17/1986	Thomas O'Connor
	Benthic Surveillance 1986	05/01/1986	06/19/1986	Bruce McCain
	NOAA'S Duwamish River Study	05/01/1986	06/20/1986	
	NOAA Nat'l Status & Trends mussel watch	12/12/1986	02/23/1987	Thomas O'Connor
	NOAA Nat'l Status & Trends mussel watch	11/18/1987	01/27/1988	Thomas O'Connor
	Benthic Surveillance 1989	05/16/1989	05/18/1989	Bruce McCain
	NOAA chinook salmon bioaccum. study	05/23/1989	06/28/1990	Usha Varanasi
	Pacific Marine Center Sediment Survey	06/30/1994	06/30/1994	
Port of Port Townsend	Port Townsend Harb. Exp. study (prelim).	12/20/1989	12/20/1989	D. Kendall (Corps)
Port of Seattle	Port of Seattle/Terminal 105 Dredging 85	06/20/1985	06/20/1985	Doug Hotchkiss
	Lockheed Shipyard 2 Sed Char/Geotch Stdy	08/29/1989	09/16/1989	
	Pier 64/65 Sediment Quality Assessment	05/09/1990	06/05/1990	
	Terminal 5 W. Waterway maint. dredging	06/14/1991	06/19/1991	Doug Hotchkiss
	Terminal 91, W. side apron construction	11/05/1991	11/11/1991	Doug Hothckiss
	American President's Line maint. dredge	03/30/1992	03/30/1992	D. Kendall (Corps)
PTI	EPA study of crab tissue dioxins/furans	03/11/1991	03/11/1991	
PTI for Washington Department of Ecology	PSDDA Phase I Survey of Disposal Sites	05/06/1988	06/11/1988	Paula Ehlers
Puget Sound Ambient Monitoring Program	PSAMP trawl data for 1989	04/01/1989	04/01/1989	
	PSAMP trawl data for 1991	05/01/1991	05/01/1991	
	PSAMP trawl data for 1992	05/01/1992	05/01/1992	
	PSAMP trawl data for 1993	04/01/1993	04/01/1993	

Appendix J. Continued.

Agency Name	Survey Name	Beginning date	Ending date	Chief Scientist
Roy F. Weston	Lower Duwamish River -Site Inspection	08/11/1998	09/23/1998	
Seattle METRO	1982 ALKI Survey	05/25/1984	05/26/1984	
U.S. Army Corps of Engineers - Seattle	Duwamish R. maintenance dredge, Phase 1	08/28/1990	08/28/1990	D. Fox (Corps)
	Keystone Harbor Study/Maint. Dredging.	12/07/1990	12/07/1990	D. Kendall (Corps)
	U.S. Navy Bremerton Pier D	03/25/1991	04/01/1991	Peter Havens (USN)
	Lonestar Northwest - West Terminal	05/29/1992	06/03/1992	D. Kendall (Corps)
U.S. Coast Guard	US Coast Guard dredging and construction	09/19/1989	09/19/1989	D. Kendall (Corps)
U.S. Corps of Engineers	Seattle, Port of, Terminal 5, DY97	01/01/1996	01/17/1996	
U.S. EPA	Lake Union Sediment Investigation	03/20/1984	03/21/1984	James Hileman
	Puget Sound Salmon Net Pen Survey	03/27/1991	09/09/1991	Dr. Chip Hogue
U.S. EPA, Region 10, Seattle, WA	1982-83 EPA survey of Duwamish River	09/01/1982	07/28/1983	
	1985 Elliott Bay sediment survey	09/25/1985	10/16/1985	
	PugetSound Reconnaissance; Dyes Inlet	04/21/1988	04/22/1988	Eric Crecelius
	Puget Sound Reconnaissance Survey - Spri	04/19/1988	05/28/1988	Eric Crecelius
U.S. Navy, Facil. Eng. Com., Silverdale.	US Navy Manchester Fuel Pier Replacement	04/05/1989	04/12/1989	Joseph DiVittorio
UNIMAR / GEO Engineers Inc.	UNIMAR Drydock (Yard 1) Sampling 1991	01/29/1991	01/29/1991	James A. Miller
URS Consultants, Inc.	Puget Snd Naval Shipyard Site Inspec. 90	11/29/1990	12/12/1990	Allen Rose
	Navy/Keyport Final RI Report of 10/25/93	08/12/1989	08/18/1992	
	The Navy's Keyport RI Report	08/12/1989	09/17/1992	
	Sinclair Inlet monitoring, 1994	03/16/1994	07/14/1994	

Appendix J. Continued.

Agency Name	Survey Name	Beginning date	Ending date	Chief Scientist
US Army Corps of Engineers	Seattle, Port of, T18 Phase 1, DY97	01/01/1996	03/16/1996	
US EPA (Weston prime; PTI sub)	Harbor Island Phase II RI	09/24/1991	10/31/1991	Chip Hogue
USACE (U.S. Corps of Engineers)	Sinclair Inlet Marina, DY94	07/14/1993	07/14/1993	
	PSDDA Report: '93 Des Moines Marina	09/28/1993	09/29/1993	
	Port of Seattle Terminal5 Pier Extension	06/14/1994	08/06/1994	
	Crowley Marine Services, DY96	07/13/1995	07/18/1995	
	Port of Seattle, T18 Phase 2, DY97	01/01/1996	06/12/1996	
UW Department of Oceanography	PugetSound & Strait JdF Grain Size	06/19/1950	03/01/1973	Richard W. Roberts
WA Department of Ecology, EILS Program	Survey for Contaminants at Paine Field	08/10/1987	08/11/1987	Art Johnson
	Bremerton WTP Class II Inspection	01/25/1988	01/25/1988	Don Reif
	Central Kitsap WTP 1988 Class II Inspec.	11/28/1988	11/28/1988	Marc Heffner
	Port Orchard WTP Class II Inspection	01/17/1989	01/17/1989	Lisa Zinner
	Edmonds WTP Class II Inspection	04/17/1989	04/17/1989	Jeanne Andreasson
	Survey of Contaminants in Lake Union	06/18/1990	06/20/1990	James Cubbage
	Olympus Terrace WTP Class II Inspection	03/19/1992	03/19/1992	Steven Golding
WA Dept. of Parks and Recreation.	WA state park maintenance dredging.	09/07/1988	09/07/1988	Joe Giustino
Washington Department of Ecology	Eagle Harbor sediment chemistry survey	06/01/1985	06/01/1985	
	PSAMP Sediment Monitoring 1989	01/01/1989	12/31/1989	
	PSAMP Sediment Monitoring 1990	01/01/1990	12/31/1990	
	PSAMP Sediment Monitoring 1991	01/01/1991	12/31/1991	
	PSAMP Sediment Monitoring 1992	01/01/1992	12/31/1992	
	PSAMP Sediment Monitoring 1993	01/01/1993	12/31/1993	

Appendix J. Continued.

Agency Name	Survey Name	Beginning date	Ending date	Chief Scientist
	PSAMP Sediment Monitoring 1994	01/01/1994	12/31/1994	
	PSAMP Sediment Monitoring 1995	01/01/1995	12/31/1995	
	PSAMP Sediment Monitoring 1996	01/01/1996	12/31/1996	Maggie Dutch
Washington Department of Ecology, TCP	Seattle Commons Sediment Sampling Report	03/04/1994	03/04/1994	Teresa Michelsen
Washington Department of Ecology, Water Quality Invest.	Port Townsend Pen-Reared Salmon Mortal.	11/30/1987	11/30/1987	Art Johnson
Washington Dept. of Fisheries	Rockfish Monitoring Survey, Fall 1989	10/05/1989	11/02/1989	O'Neill & Schmitt
	Pacific Cod Monitoring Survey, Winter 90	02/27/1990	03/08/1990	O'Neill & Schmitt
	Pacific Salmon Monitor.Survey, Spring 90	04/23/1990	05/02/1990	O'Neill & Schmitt
	Rockfish Monitoring Survey, Fall 1991	10/30/1991	01/08/1992	O'Neill & Schmitt
	Pacific Cod Monitoring Survey, Winter 92	02/27/1991	03/04/1992	O'Neill & Schmitt
Washington Dept. of Natural Resources	1990 PSDDA Post-Disposal Site Monitoring	05/15/1990	07/19/1990	Gene Revelas
	Aq. Lands Sediment Qual. Reconnaissance.	02/08/1991	02/13/1991	B. Striplin
	Aq. Lands Sediment Qual. Reconnaissance.	01/20/1992	01/25/1992	Phil Herzog
	1992 PSDDA full monitoring, Elliott Bay	06/11/1992	06/19/1992	Gene Revelas
WWU,NOAA,OSU	Misc. PS Reference area grain size	11/23/1981	07/01/1987	Dewitt,Broad,Chapm
Wyckoff Company	Wyckoff Effluent Investigation: Baseline	12/10/1989	12/10/1989	K. Jennings/ATT
	Wyckoff Effluent Investigation: 4th Qtr.	01/11/1991	01/11/1991	J. Fegley/ATT
Unknown	1985 Puget Sound Eight-Bay survey.	08/06/1983	05/29/1984	
Unknown	US Navy Bremerton Pier D, Round 2, DY94	08/09/1993	09/24/1993	

Appendix K

National and Washington State Sediment Guidelines.

Appendix K. National and Washington State Sediment Guidelines.

	National Guidelines[1]			Washington State Sediment Management Standards[2]		
Compound	**ERL[3]**	**ERM[4]**	**Unit**	**SQS[5]**	**CSL[6]**	**Unit**
Trace metals						
Arsenic	8.2	70	PPM Dry Weight	57	93	PPM Dry Weight
Cadmium	1.2	9.6	PPM Dry Weight	5.1	6.7	PPM Dry Weight
Chromium	81	370	PPM Dry Weight	260	270	PPM Dry Weight
Copper	34	270	PPM Dry Weight	390	390	PPM Dry Weight
Lead	46.7	218	PPM Dry Weight	450	530	PPM Dry Weight
Mercury	0.15	0.71	PPM Dry Weight	0.41	0.59	PPM Dry Weight
Nickel	20.9	51.6	PPM Dry Weight	NA	NA	PPM Dry Weight
Silver	1	3.7	PPM Dry Weight	6.1	6.1	PPM Dry Weight
Zinc	150	410	PPM Dry Weight	410	960	PPM Dry Weight
Organic Compounds						
LPAH						
2-Methylnaphthalene	70	670	PPB Dry Weight	38	64	PPM Organic Carbon
Acenaphthene	16	500	PPB Dry Weight	16	57	PPM Organic Carbon
Acenaphthylene	44	640	PPB Dry Weight	66	66	PPM Organic Carbon
Anthracene	85.3	1100	PPB Dry Weight	220	1200	PPM Organic Carbon
Fluorene	19	540	PPB Dry Weight	23	79	PPM Organic Carbon
Naphthalene	160	2100	PPB Dry Weight	99	170	PPM Organic Carbon
Phenanthrene	240	1500	PPB Dry Weight	100	480	PPM Organic Carbon
Sum of LPAHs:						
Sum of 6 LPAH (WA Ch. 173-204 RCW)	NA	NA		370	780	PPM Organic Carbon
Sum of 7 LPAH (Long et al., 1995)	552	3160	PPB Dry Weight	NA	NA	
HPAH						
Benzo(a)anthracene	261	1600	PPB Dry Weight	110	270	PPM Organic Carbon
Benzo(a)pyrene	430	1600	PPB Dry Weight	99	210	PPM Organic Carbon
Benzo(g,h,I)perylene	NA	NA		31	78	PPM Organic Carbon

Chrysene	384	2800	PPB Dry Weight	110	460	PPM Organic Carbon
Dibenzo(a,h)anthracene	63.4	260	PPB Dry Weight	12	33	PPM Organic Carbon
Fluoranthene	600	5100	PPB Dry Weight	160	1200	PPM Organic Carbon
Indeno(1,2,3-c,d)pyrene	NA	NA		34	88	PPM Organic Carbon
Pyrene	665	2600	PPB Dry Weight	1000	1400	PPM Organic Carbon
Total Benzofluoranthenes	NA	NA		230	450	PPM Organic Carbon
Sum of HPAHs:						
Sum of 9 HPAH (WA Ch. 173-204 RCW)	NA	NA		960	5300	PPM Organic Carbon
Sum of 6 HPAH (Long et al., 1995)	1700	9600	PPB Dry Weight	NA	NA	
Sum of 13 PAHs	4022	44792	PPB Dry Weight	NA	NA	
Phenols						
2,4-Dimethylphenol	NA	NA		29	29	PPB Dry Weight
2-Methylphenol	NA	NA		63	63	PPB Dry Weight
4-Methylphenol	NA	NA		670	670	PPB Dry Weight
Pentachlorophenol	NA	NA		360	690	PPB Dry Weight
Phenol	NA	NA		420	1200	PPB Dry Weight
Phthalate Esters						
Bis (2-Ethylhexyl) Phthalate	NA	NA		47	78	PPM Organic Carbon
Butylbenzylphthalate	NA	NA		4.9	64	PPM Organic Carbon
Diethylphthalate	NA	NA		61	110	PPM Organic Carbon
Dimethylphthalate	NA	NA		53	53	PPM Organic Carbon
Di-N-Butyl Phthalate	NA	NA		220	1700	PPM Organic Carbon
Di-N-Octyl Phthalate	NA	NA		58	4500	PPM Organic Carbon
Chlorinated Pesticide and PCBs						
4,4'-DDE	2.2	27	PPB Dry Weight	NA	NA	
Total DDT	1.58	46.1	PPB Dry Weight	NA	NA	
Total PCB:						
Total Aroclors (WA Ch. 173-204 RCW)	NA	NA		12	65	PPM Organic Carbon
Total congeners (Long et al., 1995)	22.7	180	PPB Dry Weight	NA	NA	

Appendix K. Continued.

Miscellaneous Compounds					
1,2-Dichlorobenzene	NA	NA	2.3	2.3	PPM Organic Carbon
1,2,4-Trichlorobenzene	NA	NA	0.81	1.8	PPM Organic Carbon
1,4-Dichlorobenzene	NA	NA	3.1	9	PPM Organic Carbon
Benzoic Acid	NA	NA	650	650	PPB Dry Weight
Benzyl Alcohol	NA	NA	57	73	PPB Dry Weight
Dibenzofuran	NA	NA	15	58	PPM Organic Carbon
Hexachlorobenzene	NA	NA	0.38	2.3	PPM Organic Carbon
Hexachlorobutadiene	NA	NA	3.9	6.2	PPM Organic Carbon
N-Nitrosodiphenylamine	NA	NA	11	11	PPM Organic Carbon

[1] Long, Edward R., Donald D. Macdonald, Sherri L. Smith and Fred D. Calder. 1995. Incidence of adverse biological effect with ranges of chemical concentrations in marine and estuarine sediments. Environmental Management 19(1): 81-97.
[2] Washington State Department of Ecology. 1995. Washington State Sediment Management Standards, Chapter 173-204 RCW.
[3] ERL – Effects Range Low
[4] ERM – Effects Range Median
[5] SQS – Sediment Quality Standards
[6] CSL – Cleanup Screening Levels